The dynamics of surprise and curiosity

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Cover design: Noordewier & de Jong
Printed by: Ipskamp Drukkers

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PROEFSCHRIFT

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden
op gezag van Rector Magnificus prof. mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op woensdag 24 februari 2016
klokke 16.15 uur.

Door
Marret Kathelijn Noordewier
geboren te Leeuwarden
in 1981

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Prologue

The dynamics of surprise and curiosity

Not everything makes sense. Things change and people are often confronted with unexpected or novel situations that are not completely understood right away. These "not knowing" situations trigger specific affective states or emotions, such that people experience surprise when confronted with an unexpected event (Meyer, Reisenzein, & Schützwohl, 1997) and feel curious when they realize they have a gap in their information (Loewenstein, 1994; Silvia, 2005). Surprise and curiosity are thus related to people's knowledge or understanding of their environment and for that reason they are also referred to as knowledge or epistemology-based states (Keltner & Shiota, 2003; Silvia, 2008).

Surprise and curiosity are typically temporary. People are sensemakers and often resolve their lack of knowledge or understanding. As such, these knowledge states unfold from not knowing something to discovering what it is all about. Surprise and curiosity are thus dynamic states that change depending on where people are in their process of making sense. Based on this, I[1] will argue and show that to understand surprise and curiosity it is key to take these dynamics of sense-making into account. Only then, it is possible to meaningfully distinguish the not knowing component from the subsequent (almost) knowing component.

The starting point of the work described in this dissertation is that not knowing something feels very different from (almost) knowing something. Not knowing is likely to be experienced as unpleasant. An abundance of research in the domain of cognitive consistency (Aronson et al., 1968; Gawronski & Strack, 2012), fluency (Topolinski, 2013; Winkielman & Cacioppo, 2001), personal control (Kay, Whitson, Gaucher, & Galinsky, 2009), and information search (Loewenstein, 1994; Shani, Tykocinski, & Zeelenberg, 2008) all points to the notion that inconsistency, knowledge deprivation, lack of structure, or uncertainty is aversive because it threatens people's need for a predictable and coherent world (see also Miceli & Castelfranchi, 2015; Proulx, Inzlicht, & Harmon-Jones, 2012). The not knowing component

[1] Science is a collaborative effort and even though this dissertation is single-authored, the work is done in close collaboration with others. Therefore, I refer to "we" after this prologue.

of surprise and curiosity is therefore likely to be experienced as negative.

Contrary to this not knowing, (almost) knowing something can be very enjoyable. People are exploratory creatures who like to discover something new (Berlyne, 1971; Kashdan & Silvia, 2009; Silvia & Kashdan, 2009). Therefore, the anticipation of resolving one's lack of knowledge is likely to be experienced as pleasant (Loewenstein, 1994) and once understood, a previously unknown outcome may be nice (Valenzuela, Strebel, & Mellers, 2010). So, opposite from the not knowing component, the (almost) knowing component of surprise and curiosity has the potential to be positive.

In this dissertation, I aim to show that it is possible to integrate the not knowing versus (almost) knowing components of surprise and curiosity when taking the dynamics of sense-making into account. In Part 1, I focus on surprise and the temporal unfolding of responses to surprising outcomes. In Part 2, I focus on curiosity and the impact of feeling close to its resolution in terms of time and feeling able to deal with the unknown.

Part 1: Surprise

People anticipate and understand their environment using schematic representations and expectancies (Miceli & Castelfranchi, 2015). Yet, no matter how cognitively prepared people are, they are frequently confronted with unexpected outcomes. When surprised, ongoing thoughts and activities are interrupted, and attention is directed to the surprising stimulus to make sense of it (Horstmann, 2015; Meyer et al., 1997; Reisenzein, 2000b). Once the surprising stimulus is cognitively mastered (Attardo, 1997; Forabosco, 1992; Suls, 1972; Topolinski, 2013) surprise dissipates and other affective states follow depending on the valence of the surprising event (Ekman, 2003; Tomkins, 1984). In other words, people first respond to the unexpectedness of an event and only after people had time to make sense, they respond to the valence of the event.

Following these temporal dynamics of sense-making, the first chapter of this dissertation is a review and integration of theories and empirical evidence on surprise. I distinguish surprise as initial interruption due to inconsistency or disfluency from subsequent states that follow after people cognitively master the surprising stimulus. I discuss methodological implications of this perspective and review cognitive and experiential consequences of surprise by arranging them onto the interruption-to-mastering timeline.

In the second chapter, I use this temporal framework to empirically explore the possibility that surprise feels negative. That is, because the lack of understanding of unexpected outcomes is in conflict with people's need for a predictable and coherent world, it is likely to feel negative (Miceli & Castelfranchi, 2015; Proulx et al., 2012). I investigate how linguistic features of surprise and its temporal dynamics may have contributed to previous confusion regarding its valence. Specifically, I use autobiographical recall of unexpected and surprising events and facial expressions of surprise to distinguish responses to the unexpectedness of an event from responses to the valence of the event.

In the third chapter, I more systematically investigate the unfolding of facial expressions after a surprising event. I reason that if surprise feels relatively negative, initial facial expressions to positive surprises should be more negative than later expressions. In addition, expressions to positive and negative surprises should be initially similar. Finally, I investigate the possibility that the surprised face involves frowning and test how different facial actions (e.g., frowns, brow raises, smiles) develop over time.

Taken together, Part 1 of this dissertation aims to show that to understand surprise, it is key to take the temporal dynamics of sense-making into account. The chapters provide a test of the logic that surprise is the initial interrupted state in which people do not (yet) understand what has happened, which is different from the subsequent state that people experience immediately after making sense of the stimulus. Next, I take the dynamics of sense-making to better understand curiosity.

From Surprise to Curiosity

Curiosity is triggered when people become aware of a gap in their knowledge, for instance when they have incomplete information or when they are confronted with something novel and complex that they do not understand completely right away (Kashdan & Silvia, 2009; Litman, 2005; Loewenstein, 1994; Silvia & Kashdan, 2009). Like surprise, curiosity can thus be the result of unexpectedness, but there are more causes. Just missing information can also make people curious, for instance, when people do not know what will happen or when they do not have the answer to a question (Berlyne, 1960; Loewenstein, 1994; Miceli & Castelfranchi, 2015). Situations that induce curiosity are thus broader than situations that induce surprise.

Curiosity instigates exploratory behavior, aimed at resolving the lack of information (Loewenstein, 1994; Silvia, 2012; Van Dijk & Zeelenberg, 2007). As such, curiosity is a state in which people have an information-gap but at the same time anticipate that they will resolve it. Surprise and curiosity thus share that there is something unknown that people want to resolve. Yet, while the key component of surprise is the interruption as a result of an unanticipated outcome, curiosity is better described as a state of lacking information with the anticipation that the resolution will follow. In other words, surprise is the "undecided" state in which people do not yet know whether to approach or avoid the event (Scherer, Zenter, & Stern, 2004), while curiosity refers to the motivation to explore the unknown (Silvia, 2005).

It should be noted, however, that people do not mindlessly explore the unknown. An important precondition for exploration is that people estimate that they have the skills, knowledge, and resources to deal with the event (i.e., coping potential, Silvia, 2005). This means that people will only engage in exploratory behavior to resolve their information-gap, when they feel able to cope with it (Silvia, 2005). Coping potential is particularly an issue when people are confronted with complex and/or novel events. Relative to more simple and familiar events, complex and/or novel events are more likely to interfere with people's understanding of their environment. So, instead of exploring all that is unknown, people will be less inclined to do so when the information-gap is appraised to be too difficult to deal with. Note that this logic also implies that it is possible to shift from surprise to curiosity, but only when people feel they can cope with the unexpected event (see also sequential appraisals in Scherer, 2001, and Chapter 2).

In Part 2 of this dissertation, I build on the notion that curiosity involves both not knowing something and the anticipation of resolving this, to investigate how it feels to be curious. Moreover, I relate feeling able to deal with the unknown to interest in complex novelty.

Part 2: Curiosity

Based on the notion that curiosity is a combination of not knowing and almost knowing, in the fourth chapter of this dissertation, I investigate how time affects the subjective experience of curiosity. Specifically, I reason that the temporal proximity of the resolution of curiosity affects the relative impact of the not knowing (information-gap) vs. almost knowing component (anticipation of resolution). When people do not expect to close their information-gap soon (long time to the resolution), the anticipation of the resolution is weaker and not knowing is predicted to affect the experiential content of curiosity more strongly than when they expect to close their information-gap quickly (short time to the resolution). Because not knowing feels more negative than almost knowing, curiosity is predicted to feel more unpleasant the further in time the resolution.

Next, in the fifth chapter, I build on the fact that people need coping potential in order to be motivated to explore the unknown. Specifically, I investigate the relation between coping potential and interest in complex novelty. Complex novelty, like new products or technologies, can be exciting in terms of promising possibilities, but also challenging because people do not exactly grasp its meaning or purpose. To become curious and interested in complex novelty it is therefore key that people have a sense that they can cope with it. I investigate this for both actual coping potential (product-specific understanding) and perceived coping potential (a general coping state that makes people able to tolerate the difficulty component of complex novelty).

In the current framework, I focus on the similarities between curiosity and interest, based on their shared exploratory motivation (see also Kahsdan & Silvia, 2009). It should be noted, however, that some researchers differentiated between curiosity and interest by arguing, for instance, that curiosity is more unpleasant and short-lived than interest (e.g., Hidi & Berndorff, 1998; Loewenstein, 1994). Situational curiosity is often (but not exclusively) studied with relatively specific and clear information-gaps (e.g., a box containing something round; see Van Dijk & Zeelenberg, 2007; or answers to knowledge questions, Litman, Hutchins, & Russon, 2005; see also Chapter 4). Interest, on the other hand, is typically studied in more complex and diffuse domains (e.g., art appreciation or learning, see Hidi & Berndorff, 1998; Silvia, 2005; Chapter 5) and even defined as such (i.e., novelty-complexity as one of the underlying appraisals of interest; cf. Silvia, 2005). In studies on curiosity it is therefore often clearer what piece of information is missing than in studies on interest. As such, curiosity can be resolved with finding this specific missing information, whereas with interest, discovering one thing may motivate finding out more. This not only makes interest last longer, it is also likely to be more pleasant as there are many more possibilities for gaining knowledge than with the more specific information-gap of curiosity (see also the discussion on lack of informational end-point in Chapter 4).

While there are thus reasons to differentiate between curiosity and interest, it also seems that the assumed differences are at least partly a byproduct of the domains in which curiosity and interest are studied. In addition, while perceptual curiosity (attention to novel visual, auditory, or tactile stimuli, see Berlyne, 1954; Collins, Litman, & Spielberger, 2004) may fit the perspective of clear information-gaps, with epistemic curiosity this becomes more difficult. Epistemic curiosity is the desire for knowledge aroused by conceptual puzzles or (complex) ideas (Berlyne 1954; Litman & Spielberger, 2003). This thus also includes more complicated and diffuse topics making it hard to distinguish it from interest (see also the concept of diversive curiosity in Berlyne, 1960). In general, there are thus many similarities between curiosity and interest and for the sake of parsimony, in this dissertation I focus on the features they share.

Finally, a note about the chapters that will follow: The chapters are written as (empirical) journal articles and they can be read independently and there is some overlap. Moreover, due to changing times in social sciences (cf. Kline, 2013), the different chapters contain somewhat different statistical methods to test the hypotheses. This is a reflection of different requirements of journals moving away from only performing null hypothesis significance testing procedures (Cumming, 2015; Trafimow & Marks, 2015) and a general trend toward promoting good research practices (Simmons, Nelson, & Simonsohn, 2011, 2013).

PART I
SURPRISE

CHAPTER 1

The temporal dynamics of surprise

A revised version of this chapter can be found in: Noordewier, M. K., Topolinski, S., & Van Dijk, E. (2016). The temporal dynamics of surprise. *Social and Personality Psychology Compass, in press.*

The Temporal Dynamics of Surprise

People are surprised when they are confronted with unexpected or schema-discrepant stimuli (Ekman, 2003; Horstmann, 2006; Meyer, Niepel, Rudolph, & Schützwohl, 1991; Meyer, Reisenzein, & Schützwohl, 1997; Smedslund, 1990). According to this view, surprise is a function of the difference between an expected and an actual outcome, like winning when one expected to lose (see also Teigen & Keren, 2003). This does not necessarily imply that people need explicit expectancies to be surprised. Surprise can also be evoked when people are confronted with something that does not fit their general schematic representation of the situation. When, for instance, a fluffy bunny hops into one's office, this is not surprising in the sense that people explicitly expected something different. This bunny may come as a surprise because it is not prototypical of one's representation of the situation, in this case, a business setting (see also misexpected vs. unexpected in Macedo, Cardoso, Reisenzein, Lorini, & Castelfranchi, 2009). Surprise thus reflects the difficulty in integrating or merely processing a disfluent or inconsistent event in a given representation (Kahneman & Miller, 1986; Maguire, Maguire, & Keane, 2011; Miceli & Castelfranchi, 2015; Topolinski & Reber, 2010a) and it is the interrupted state in which people do not (yet) know what has happened (see also Meyer et al., 1991, 1997).

In the current review, we will integrate theories and empirical evidence on surprise guided by a temporal dynamics perspective on surprise and sense-making (see Meyer et al., 1991, 1997; Noordewier &

Breugelmans, 2013; Pezzo, 2003). We distinguish surprise as the *initial state* that represents a cognitive interruption as a result of inconsistency or disfluency from *subsequent states* after people cognitively master the presence of the stimulus. To understand the nature and consequences of surprise, it is thus key to take time into account. We will arrange surprise research onto this interruption-to-mastering timeline with the goal to distinguish surprise from its consequences and to explain (seemingly) contradicting findings. We do this by a) critically discussing methods used in surprise research and b) reviewing different models and findings on the cognitive and experiential content of surprise, where we also integrate conceptually similar research in which it is not typical to refer to surprise (e.g., cognitive consistency, processing fluency, and immediate cortical responses such as the P300).

The Time Course of Surprise: From Interruption to Mastering

The time course of surprise starts with the detection of something unexpected. When people are surprised, ongoing thoughts and activities are interrupted, and attention is automatically directed to the surprising stimulus (Darwin, 1872/1998; Horstmann, 2006, 2015; Meyer et al., 1991, 1997; Plutchik, 1980; Reisenzein, 2000b; Scherer, 2001). The stronger the unexpectedness (e.g., because of stronger expectancies/schema's) the more intense the surprise (Schützwohl, 1998). Once the surprising stimulus is cognitively mastered (Attardo, 1997; Forabasco, 1992; Suls, 1972; Topolinski, 2013) surprise dissipates and other affective states follow depending on the valence of the surprising event (Ekman, 2003; Noordewier & Breugelmans, 2013; Tomkins, 1984).

Thus, people first respond to the unexpectedness of an event, independent of its valence, and then responses unfold contingent on the valence of the event, such as joy for positive events and sadness or anger for negative events. As such, the temporal time course of surprise involves the unfolding of responses from initial interruption to cognitive mastering—similar to the sequential appraisal perspective on emotion (Scherer, 2001), where the appraisal of an event being sudden, unfamiliar, or unpredictable (i.e., novelty-check) *precedes* appraising the event in terms of pleasantness, goal conduciveness, or coping potential. Importantly, this means that surprise itself is different from the state that people experience immediately after making sense of the stimulus.

The notion that time is important for surprise and its consequences originates from Meyer et al.'s (1991, 1997) cognitive-evolutionary model of surprise (for reviews, see Macedo et al., 2009; Reisenzein, 2000b; Reisenzein, Meyer, & Niepel, 2012). This model identifies sequential processing steps and states that surprising events first elicit the appraisal of schema-discrepancy, followed by interruption of ongoing information processing and the reallocation of processing resources together with the feeling of surprise. The process ends with the analyses and evaluation of the event and, if necessary, the updating or revision of schemas. We build on this model and mainly focus on the interruption part where people feel surprise. This initial interruption and feeling of surprise is, in our view, the main experiential component of surprise (see also Miceli & Castelfranchi, 2015), and experientially different from the part that follows when people analyzed the event and master the outcome. So, where Meyer et al.'s model focuses on the *sequence of processing steps* to provide a complete overview of *all* consequences after being confronted with a schema-discrepant event (cf. Meyer et al., 1997), we follow their logic to *differentiate* surprise as the *initial interrupted state* from *subsequent states* that follow after people cognitively master the surprising stimulus. In the terminology of Meyer et al.'s model, this initial state thus represents the feeling of surprise, the interruption of processing and reallocation of processing resources and the very first part of the analysis of the event—as long as people do not yet master event. This follows the definition of Reisenzein et al. (2012), who stated that surprise is the "output signal of the unexpectedness detector".

By distinguishing surprise from its consequences, we aim to provide a clearer conceptualization of what surprise is and how it feels. Specifically, in what follows, we will take the time course of surprise to 1) point out methodological implications, 2) review initial cognitive consequences that support the notion that surprise is initially interrupting and independent of the nature of the stimulus, and 3) integrate apparently contradictory findings concerning the experiential content of surprise.

Implications of Temporal Dynamics for Methodology

As methods differ in terms of timing, so do conclusions that can be drawn from them. Below we review various methods in terms of whether they primarily focus on the initial or later consequences of surprise. Specifically, there are many methods that induce surprise in participants, which offer the possibility to focus on surprise *while it happens*. Importantly, however, not all dependent measures are equally suitable to tap into the initial interruption. Indeed, many measures that claim to assess surprise, merely assess the consequences of surprise at a later stage. Moreover, there are also methods that do not focus on surprise while it happens but rather focus on associations, interpretations, or memories. This limits the possibility to study the experience of surprise without confusing it with the state that follows it.

Inducing Surprise

Inducing surprise is typically done by presenting stimuli that are incongruent to representations brought to the empirical setting (cf. *general knowledge structures*, e.g., Bless, Clore, Schwarz, Golisano, Rabe, & Wölk, 1996), or by disconfirming an expectancy that has been created within the empirical setting itself. Surprise has, for instance, been induced by a change in the experimental setting like changing the voice of the experimenter (Scherer et al., 2004) or even by transforming a complete corridor into a new room (Schützwohl & Reisenzein, 2012). Explicitly violating expectancies is often done via repetition-change paradigms (i.e., a different target stimulus after repeated exposure to a stimulus), such as presenting big/green letters after a series of one small/grey letter (Schützwohl & Borgstedt, 2005), or by changing the location of the experimenter in a sequential peek-a-boo game with infants (Parrott & Gleitman, 1989). Other expectancy-based methods include expectancy/ stereotype-inconsistent person descriptions or interactions (e.g., a sporty elderly woman; Macrae, Bodenhausen, Schloerscheidt, & Milne, 1999; Mendes, Blascovich, Hunter, Lickel, & Jost, 2007; see also Gendolla & Koller, 2002), semantically unpredictable sentences (Whittlesea, 1993), good news after having read that bad news was more likely (Sheppard & McNulty, 2002), or success after predicting failure is more likely (McGraw, Mellers, & Ritov, 2004).

Measuring (correlates of) Surprise

While these diverse induction methods most likely all result in surprise, dependent measures differ in terms of whether they focus on the initial interruption or on the state after cognitive mastering. Measures that can capture the initial interruption include facial expressions (e.g., Reisenzein et al., 2006), coding the absence or presence of a surprised expression using for instance FACS (Ekman, Friesen, & Hager, 2002); facial electromyography (fEMG, e.g., Topolinski, Likowski, Weyers, & Strack, 2009; Topolinski & Strack, 2015) or expression coding software (e.g., FaceReader; see Chapter 3), sometimes including measures of pupil dilation and vocalizations (Reisenzein et al., 2006). Also, various physiological measures can measure initial correlates of surprise, including arousal (e.g., Niepel, 2001), physiological threat responses (Mendes et al., 2007), and central nervous correlates obtained with EEG or fMRI (e.g., Alexander & Brown, 2011; Egner, 2011).

Many dependent variables do, however, *not* tap into surprise while it happens, but instead focus on consequences of surprise after cognitive mastering. First of all, self-reported surprise (e.g., Maguire et al., 2011; Reisenzein, 2000a; Schützwohl & Borgstedt, 2005; Teigen & Keren, 2003) is often assessed when participants already made sense of the surprising target. While people might be able to report how intensely they experienced surprise, this measure does not necessarily reflect the original experience of surprise while it happened because it is likely to be influenced by a retrospective evaluation of the event (see also Schützwohl, 1998). Also, when people report that they were *not* surprised, it is possible that they actually were surprised but meanwhile have re-interpreted the situation, such as in hindsight bias (Hawkins & Hastie, 1990). Similarly, self-ratings of related affective states or evaluative judgments most likely reflect consequences of surprise rather than experiential correlates of surprise itself (e.g., Mellers et al., 1997; Valenzuela et al., 2010). Concluding, self-reports of surprise and other affective states assessed after cognitive mastering are likely affected by various mechanisms different from surprise itself.

Indirect Methods

Besides inducing surprise in participants with inconsistent, disfluent, or unexpected outcomes, scientific knowledge about surprise has also benefitted from relatively indirect methods. Indirect methods do not focus on surprise while it happens but rather focus on associations, interpretations, or memories.

For instance, in linguistic methods participants rated the extent to which emotions, including surprise, fit words related to arousal and valence (Russell, 1980) or affective states, appraisals, and actions (Fontaine, Scherer, Roesch, & Ellsworth, 2007). While these methods are suitable to study the dimensional structure of longer lasting emotions, they may not reflect the actual experiential properties of the short-lived experience of surprise. The associations people report are potentially mixed and may not represent the initial short-lived surprise alone. The same holds for autobiographical recall of an unexpected/ surprising event. While recall supposedly regenerates feelings and participants appear able to differentiate between initial and later responses when asked to do so (Noordewier & Breugelmans, 2013), it is still possible that recollections of especially the initial interruption are influenced by the fact that participants recalled the whole experience, including the part that they already made sense of (cf. the peak-and-end rule of retrospective assessments, Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993, where the end phase of an experience dominates the later assessment).

Also, in some facial expression research, participants or actors are asked to express a certain emotion, based on an emotion label or a description of an emotional state (e.g., Du, Tao, & Martinez, 2014). This task requires actors to interpret the label or the description and come up with a fitting expression. These methods can be very suitable for perception and recognition studies (e.g., Ekman & Friesen, 1971), but are unlikely to cover the time course of surprise and particularly, the initial interruption phase of surprise. Moreover, when descriptions include the meaning of the surprising situation (e.g., happily surprised, like "receiving wonderful, unexpected news" or angrily surprised, like "when a person does something unexpectedly wrong to you", see Du et al., 2014; p. 7), the expressions probably include these interpretations rather the initial interruption, the state in which people experience difficulty integrating or processing an event.

Conclusion

The implication of the current temporal dynamics perspective for methodology is that research questions related to surprise while it happens (i.e., initial interruption) are best answered by methods that induce surprise directly *and* measure correlates immediately, whereas research questions related to the later consequences of surprise (i.e., once cognitively mastered) are best answered by methods and measures that assess consequences once people understood what has happened. With this perspective in mind, we will now discuss cognitive and experiential consequences of surprise.

Cognitive Correlates and Consequences of Initial Interruption

Several lines of research on neural mechanisms have addressed the immediate brain responses to schema-inconsistent or unexpected events. While in those approaches the term "surprise" is rarely mentioned, they examine the cortical responses to outcomes that conflict with predicted or anticipated outcomes (e.g., Bush, Luu, & Posner, 2000; Donchin, 1981), which renders this research as highly pertinent to the present review. As we will see, these instant brain responses seem to aid increasing processing depth to prepare cognitive mastering. Importantly, these responses are initially independent of the nature of the surprising stimulus, supporting the view that surprise is similar for all kinds of stimuli.

First of all, *conflict detection* (Bush et al., 2000) during *conflict monitoring* (Botvinick, Braver, Barch, Carter, & Cohen, 2001) can be conceived of as a form of surprise. In conflict detection, the medial prefrontal cortex, and particularly the anterior cingulate cortex (ACC) continuously monitor the contingencies of actions/decisions and their consequences and establishes expectancies of these contingencies from past to future actions and decisions (for reviews, see Alexander & Brown, 2010; Behrens, Woolrich, Walton, & Rushworth, 2007). If these contingency-schemata are violated, that is, if unexpected outcomes are encountered (either positive, neutral, or negative, e.g., Hajcak, 2012; Hajcak, Holyroyd, Moser, & Simons, 2005), the ACC shows an immediate increase in activity, as reflected by a negative deflection in the ongoing electroencephalogram (EEG), occurring less than 100 ms after the conflict arises, the so-called *error-related negativity* (ERN; for reviews, see Holroyd & Coles, 2002; Yeung, Botvinick, & Cohen, 2004). This ACC activity thus reflects a detection of violated expectancies within a very brief time frame and has recently been related to an aversive defense response (Hajcak, 2012; Hajcak & Foti, 2008). Functionally, ACC activity has been related to increased awareness (Lane et al., 1998) and the recruitment of control processes (Bush et al., 2000).

Another immediate cortical response to unexpected stimuli is the family of *P300* responses, or *novelty P3* (Donchin, 1981; Ferrari, 2010; Goldstein, Spencer, & Donchin, 2002). In a typical paradigm on this, participants receive numerous (often neutral) stimuli, many of which are frequent or expected, but some are infrequent or unexpected (e.g., in an oddball-paradigm, Ferrari, 2010; Picton, 1992). During this, time-locked signals in the EEG, event-related potentials (ERPs) are measured. This feature of expectedness as crucial manipulation in all these paradigms again renders this research as conceptually important for the more general psychology of surprise. It should be noted, however, that surprising stimuli are not necessarily the same as infrequent stimuli (see also surprise vs. rarity in Horstmann, 2015). Infrequent stimuli are only occasionally, but typically more than once, presented in the context of frequent stimuli (e.g., in an oddball-paradigm). As such, they can be expected or even awaited. Yet, because infrequent stimuli are also considered as interrupting, this research might help to understand surprise, as processes that are similar to surprise are involved.

Taken together, a variety of studies show for surprising compared to common stimuli a positive deflection in voltage in parietal ERPs with a peak around 250 to 500 ms after stimulus-onset, the P300 (e.g., Escera, Alho, Winkler, & Näätänen, 1998; Ferrari, 2010; Goldstein et al., 2002). Crucially, the more unexpected or seemingly improbable an experimental event is, the larger the P300 is (Donchin, 1981). Similar to error-related ACC activity, functionally, the P300 has been related to the recruitment of executive functions (e.g., Näätänen, 1990).

Finally, these immediate brain responses not only trigger more elaborate processing, they also elicit an involuntary attention allocation to the surprising stimulus (Escera et al., 1998; Horstmann, 2015).

Attention Allocation. To identify the cause of the surprise, people attend to the surprising stimulus in order to makes sense of it (e.g., Escera et al., 1998; Horstmann, 2015; Meyer et al., 1991, 1997; for a discussion on surprise vs. the orienting response, see Reisenzein et al., 2012). So, after the perception of a surprising stimulus, ongoing processing is interrupted and processing resources are reallocated to attend to the surprise (for a review on the surprise-attention link, see Horstmann, 2015). Supporting the temporal dynamics perspective, attending to a surprising stimulus takes time: Because the perceptual system is not prepared for the surprising stimulus, people first have to detect the discrepancy and shift their attention, which takes more time than attending to expected stimuli (Horstmann, 2015). Once people attend to the surprising stimulus (measured by for instance reaction times, Horstmann, 2002, 2005; or eye-tracking, Horstmann & Herwig, 2015) they subsequently gaze at it (presumably to make sense of it), which lowers attention to the non-surprising surroundings (i.e., surprise-induced blindness, cf. Asplund, Todd, Snyder, Gilbert, & Marois, 2010).

Attending to the surprising stimulus is a precondition for sense-making. Processing is then aimed at establishing whether the stimulus has any relevance and whether people can or should act (Meyer et al., 1991, 1997). This process delays responses. When participants are, for example, asked to respond as quickly and accurately as possible to the position of a series of circles in a repetition-change paradigm, they respond slower when a circle changes its color. Interestingly, this effect is most pronounced when the surprising stimulus is action-relevant (i.e., a circle) as compared to action-irrelevant (i.e., a diamond; Meyer et al., 1997). So, surprise is interrupting (Meyer et al., 1991, 1997), and particularly so when it is part of goal directed behavior. Also, whereas initial responses to surprise are independent on the nature of the surprising stimulus, during the action-relevance check people start showing differentiation in responses depending on the relevance of the target.

In line with this relevance view, surprise also seems to facilitate threat detection (Schützwohl & Borgstedt, 2005). Based on the notion that threatening aspects of surprise might require immediate action, Schützwohl and Borgstedt (2005) tested whether reaction times differed depending on the valence of words. In one study, participants were asked to respond to the location of a dot above or below two animal or sports words. After a series of trials, people were shown an unpleasant (e.g., spider) or pleasant word (e.g., seal) that was either surprising or not (color was [un]expected). While in the surprise condition the pleasant and unpleasant words were evaluated to be equally surprising, participants in the surprise condition responded slower to unpleasant words (e.g., spider) than pleasant words (e.g., seal). This delay in response to the dot was assumed to reflect an increase of attentive resources to the picture and as such explained as support for threat detection.

Conclusion

Initial cognitive consequences occur very fast after a surprising event and increase depth of processing for this event. This enhanced encoding and elaboration together with the additionally recruited executive functioning all aid the process of cognitive mastering (Pezzo, 2003; Topolinski & Reber, 2010b).[2]

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[2] All this results in later increased memory for surprising stimuli (e.g., Sherman et al., 2012).

Crucially, these initial consequences are independent of the nature of the surprising stimulus. For instance, the novelty P300 occurs for surprising abstract neutral stimuli (Goldstein et al., 2002), acoustic material (e.g., Escera et al., 1998), and pictures (e.g., Ferrari, 2010). Also, it occurs for positive, neutral, and negative stimuli (e.g., Cano, Class, & Polich, 2009; Conroy & Polich, 2007; Ito, Larsen, Smith, & Cacioppo, 1998), and it is generally described as being insensitive to stimulus valence (Hajcak et al., 2005; although some find a more pronounced P300 for negative stimuli; Ito et al., 1998, Experiment 1). Only after some cognitive integration, people show differences in attention depending on the nature of the stimulus. In sum, cognitive consequences and correlates of surprise are initially the same for all kinds of stimuli. Over time—along with cognitive mastering—responses depend on the nature of the stimulus.

Experiential Content and Valence

The present temporal dynamics perspective of surprise is also informative for the ongoing debate on the experiential nature of surprise. Surprise "feels in a particular way" (Reisenzein, 2000b; p. 262), yet there is no clear answer to *how* it exactly feels to be surprised. Researchers seem to agree that surprise induces arousal, but at the same time, there are different perspectives on whether surprise feels good, bad, or neutral.

In work on the dimensional structure of emotions, people have been found to associate surprise with arousal (e.g., Fontaine et al., 2007; or astonishment in Russel, 1980) such as increased heartbeat and breath frequency, being restless and warm (for the complete list, see Fontaine et al., 2007). Direct evidence has been obtained by studies on the orienting response, where, for instance, skin conductance levels increased in response to surprising change in stimuli (e.g., Siddle, 1991; see however Niepel, 2001, who suggested that it is change rather than unexpectedness that drives arousal responses). In addition, people also appeared to have increased levels of arousal when they were instructed to mimic and experience surprise shown on a target picture (Collet, Vernet-Maury, Delhomme, & Dittmar, 1997).

It thus seems clear that surprise induces arousal, but there is less agreement on whether this is a pleasant or unpleasant state. Studies on surprise that included valence measures produced mixed results. According to some, surprise feels good (e.g., Fontaine et al., 2007; Valenzuela et al., 2010), according to others, surprise feels bad (e.g., Miceli & Castelfranchi, 2015; Noordewier & Breugelmans, 2013; Topolinski & Reber, 2010a), and it has also been argued that surprise does not have any valence (e.g., Mellers et al., 2013; Reisenzein & Meyer, 2009; Reisenzein, Meyer, & Niepel, 2012; Russel, 1980). The current timing perspective can explain and integrate these seemingly opposing findings (for a similar reasoning, see Noordewier & Breugelmans, 2013).

When zooming in on surprise as *initial interruption*, there are several reasons to depict surprise as having a negative valence. Surprise signals that an event has not been anticipated, which feels bad because it is in conflict with people's "need for prediction" (cf. Miceli & Castelfranchi, 2002, 2015). Specifically, for cognitive functioning, people need to anticipate events and validate these anticipations by facts; and if this does not happen, people experience distress (Miceli & Castelfranchi, 2015). In line with this, a prediction-error signal (i.e., ERN) has been related to an aversive defense response (Hajcak, 2012; Hajcak & Foti, 2008). Moreover, many studies in the domain of cognitive consistency (Gawronski & Strack, 2012), fluency (Topolinski, 2013; Topolinski & Strack, 2009a), and need for control (Kay et al., 2009; Rutjens et al., 2013) show that inconsistencies, disruption, and lack of structure are experienced as threatening and unpleasant as they represent a conflict with people's need for a predictable and comprehensible world (for overviews see Abelson et al., 1968; Gawronski & Strack, 2012; Miceli & Castelfranchi, 2015). Surprise implies a prediction error and reflects difficulty in encoding and semantically integrating a stimulus (Topolinski, 2012). When being surprised, reality thus does not make sense for a while. This state can be seen as dissonant, unstructured, and meaningless; all aspects that have been related to discomfort and threat (Elliot & Devine, 1994; Mendes et al., 2007; Noordewier & Breugelmans, 2013; Proulx, Inzlicht, & Harmon-Jones, 2012). Based on these longstanding research traditions, which developed relatively separately from literature on surprise, it thus seems plausible that the initial experiential disruption of surprise entails a phasic negative affect due to inconsistency or disfluency (cf. Alter, Oppenheimer, Epley, & Eyre, 2007; Winkielman & Cacioppo, 2001; Topolinski et al., 2009; Topolinski & Deutsch, 2012, 2013).

Support for this perspective can be found in a study by Mendes and colleagues (2007), who related expectancy violation to physiological threat responses. A threat (vs. challenge) response is associated with evaluating the situation as exceeding personal resources, which can be measured with distinct patterns of cardiovascular reactivity (Blascovich & Mendes, 2000). Mendes and colleagues reasoned that expectancy violation is threatening because it triggers surprise and uncertainty. In their experiments, participants interacted with a confederate who was a typical or an atypical member of his/her social category (e.g., white/Latino with high/low socio-economic status). Results showed that stereotype-consistent interaction partners were preferred over inconsistent ones (see also Schubert, Topolinski, & Strack, 2014; Swann, 1990) and atypical members elicited physiological threat responses (Mendes et al., 2007). Although further research is necessary to generalize this evidence to other surprising events or stimuli, it suggests that surprise indeed has threatening properties.

In addition, support for the reasoning that initial negativity unfolds to other affective states has been obtained by coding facial expressions over time from people who were positively surprised in TV-shows (Noordewier & Breugelmans, 2013). Participants were asked to indicate the extent to which a person in a picture felt negative or positive. The pictures were screenshots taken at one-second intervals after people were confronted with a positive surprise. Responses unfolded from relatively negative to positive, assuming to reflect the unfolding of initial responses to the unexpectedness to responses to the actual outcome.

In line with the view that *after cognitive mastering*, people respond to the nature of the stimulus, surprise has been found to be neutral or slightly positive when using linguistic methods (e.g., Fontaine et al., 2008; Russel, 1980). As discussed above, these results may reflect a mixture of surprise and associations of what followed it. Similarly, studies that included valence-related measures often administer them at a point in time where people already made sense of the surprising event. So, in terms of our perspective, they ask people how they feel or how they evaluate a surprising target *after* cognitive mastering. Then, people report being happy with a surprise gift (Valenzuela et al., 2010), satisfied by a better-than-expected performance of a product (Oliver, 1997), or delighted by an unexpected profit (Mellers et al., 1997).[3] Associations of the positive events with the word surprise might also explain why this word has more positive connotations than the word unexpected (for evidence suggesting this positive word-bias, see Noordewier & Breugelmans, 2013).

Conclusion

While more direct evidence might be needed to draw definite conclusions, the reviewed findings suggest that surprise has a negative valence, while the experience after cognitive mastering can be rewarding and positive (similar to the positive feeling of insight and punch line comprehension, Topolinski, 2013; Topolinski & Reber, 2010a). Thus, responses unfold from surprise to different states after people made sense of the stimulus. Only after cognitive mastering, people might feel good in the case of positive surprises. This dynamic

[3] Surprise can also amplify these responses (e.g., Mellers et al., 1997; Oliver, 1997; Valenzuela et al. 2010), due to an intensifying effect of residual arousal (Schachter & Singer, 1962), or because of comparison between expectancy and outcome resulting in contrast effects (e.g., Biernat, 2005).

was shown by the unfolding of facial expressions in the reviewed TV-show study (Noordewier & Breugelmans, 2013). Facial expressions thus seem to be particularly suited to study the temporal dynamics of surprise. It should be noted, however, that coding in the TV-show study focused on overall valence ratings rather than the distinct surprise expression or other specific facial features. When looking more closely to the facial expression of surprise, results become less clear.

The Face: Raised Eyebrows, Freezing, Frowning, or Nothing at All

The surprise expression has classically been conceived as involving raised eyebrows, widened eyes, and an open mouth/jaw drop (Darwin, 1872/1998; Ekman et al., 2002). Interestingly, the occurrence of this expression seems rare: Only a minority of surprised people actually shows this "typical" facial expression and those who do, show it only partly (i.e., one of the three components; e.g., Reisenzein et al., 2006).

For instance, studies with infants could not provide support for a clear facial expression of surprise. Instead, in response to surprises, infants show facial and behavioral freezing (Camras et al., 2002; Scherer et al., 2004). In these studies, a repeatedly shown toy was hidden and a different toy was revealed (Camras et al., 2002) or the voice of the experimenter changed via a speaker (see Scherer et al., 2004). Compared to baseline, surprised infants looked longer at the "impossible event" and showed more freezing (i.e., behavioral/facial stilling; see Camras et al., 2002; Scherer et al., 2004 for culture and age effects). However, they did *not* show particular surprise expressions (full or partial; but see Bennett, Bedersky, & Lewis, 2002; for a more infant expression studies, see Reisenzein et al., 2006).

Also in adults, the surprise expression is rare. Reisenzein and colleagues (Reisenzein et al., 2006) systematically tested whether surprise resulted in a surprised facial expression. They varied extremity of surprise, sociality of the context, duration and complexity of surprise, the degree to which surprise conflicts with exploration tendencies, all in different surprising contexts (e.g., when confronting participants with unanticipated photographs of themselves, Reisenzein et al., 2006; or changing a complete corridor, Schützwohl & Reisenzein, 2012). Participants reported being surprised and a majority of them also reported that they thought they had displayed a clear facial expression of surprise. Yet, only a minority of the participants actually showed a surprised face and often only partly (4-25%; Reisenzein et al., 2006; 34% in Reisenzein, 2000a).

Interestingly, in the studies reported here, the faces were mainly coded in terms of absence or presence of one or more of the three components of a surprised face (see above). It is, however, not completely clear whether participants who did not show a surprised face showed a neutral face, freezing, or signs of other facial expressions after a surprise. Sometimes, frowns were observed (Reisenzein et al., 2006: 9%/13% in Studies 3 and 8; Schützwohl & Reisenzein, 2012: 21%), as well as smiles (2-86% in Reisenzein et al., 2006; 26-71% in Schützwohl & Reisenzein, 2012; 8.6-12.1% in Scherer et al., 2004) and interest (on average 3.49 on a 5-point scale; Camras et al., 2002). In the other studies, no information about alternative expressions is available.

So, people do not seem to show the prototypical surprise expression, but they sometimes exhibit other facial signs like frowns (see also Topolinski et al., 2009; Topolinski & Strack, 2015) or smiles.

While these studies did not include time as a factor (except Study 7 in Reisenzein et al., 2006; see below), the different expressions can be placed on the interruption-to-mastering timeline. That is, freezing, frowning, the (partial) surprise expression, or no expression[4] most likely precede the smiles. Evidence for this unfolding can be found in the fEMG data in Reisenzein et al. (2006; Study 7). Participants were confronted with an unanticipated photograph of themselves in a facial judgment task. A slight increase of corrugator activity was observed after this surprising event and after 1-3 seconds this was followed by an increase in zygomaticus activity. So, a frown preceded a smile, which is in line with the current interruption-to-mastering logic (see also Noordewier & Van Dijk, 2015; Topolinksi & Strack, 2015).

Yet, based on the reviewed studies, it is not completely clear what the expression after a surprise looks like, as freezing, frowning, (partial) surprise, and neutral expressions all have been observed. Future studies should take time into account when trying to differentiate between different expressions (Noordewier & Van Dijk, 2015). In addition, other factors, like individual differences in expressivity and/or emotion regulation (e.g., Gross & John, 1997) might also partly explain

[4] It is possible that a neutral expression actually reflects freezing. Especially in stills, this might be hard to differentiate. To test the possibility of freezing in adults, it seems necessary to analyze videos, maybe even including bodily codings (e.g., Roelofs, Hagenaars, & Stins, 2010).

variations in expression. Importantly though, what freezing, frowning, and the surprise expression seem to have in common is that they all fit the initial interruption phase of surprise (Meyer et al., 1997). That is, freezing can be seen as a response that allows people to wait for further information, like sometimes observed with fear (cf. Scherer et al., 2004). Frowning has been associated with mental effort (e.g., Van Boxtel & Jessurun, 1993) and seems to be related to sense-making. Finally, it has been argued that the surprise expression helps to increase the visual field, which facilitates perception to identify the cause of the surprise (Darwin 1872/1998, see also Schützwohl & Reisenzein, 2012).

Conclusion

The temporal dynamics of surprise thus seem visible in the face. Analyzing facial expressions seems a very promising and suitable method to capture the interruption-to-mastering time line. Yet, more work needs to be done to fully understand initial interruption expression.

General Conclusion

Taking a temporal dynamics perspective on surprise (see also Meyer et al., 1991, 1997), we distinguished surprise as initial interruption from subsequent states that occur after people cognitively master the presence of the stimulus. Initially, consequences are the result of inconsistency or disfluency. Cognitive correlates (e.g., ACC/P300 activation, attention) are independent of the nature of the surprising stimulus and they all seem to increase processing depth to prepare cognitive mastering. Surprise is likely to be experienced as negative, as people do not like inconsistency, disruption, and lack of structure. Only after people cognitively master the stimulus, affective responses become in line with the valence of the stimulus. The cognitive and experiential consequences of surprise thus seem to fit the interruption-to-mastering timeline. An important implication of this temporal dynamics perspective is that methods to study surprise should be chosen carefully. Research questions related to the initial interruption phase are best answered by methods that induce surprise directly *and* measure correlates immediately, whereas research questions related to the later consequences of surprise are best answered by methods and measures that assess consequences once people understood what has happened. In sum, the temporal dynamics perspective on surprise helps to understand and integrate the nature and consequences of surprise.

CHAPTER 2

On the valence of surprise

This chapter is based on: Noordewier, M. K., & Breugelmans, S. M. (2013). On the valence of surprise. *Cognition and Emotion, 27,* 1326-1334.

On the Valence of Surprise

Common knowledge has it that it is nice to be surprised; many websites are devoted to how to throw the perfect surprise party or find the perfect gift to surprise your loved ones (e.g., www.ehow.com/topic_112_surpriseparty.html, www.surprise.com). However, psychological knowledge has it that people generally don't like surprises; people prefer predictability, consistency, and structure (Abelson et al., 1968; Gawronski & Strack, 2012). So, the question is how people feel when they are surprised. Is surprising a loved one a tragic mistake or is our psychological knowledge of how people react to surprises incomplete?

The relevance of this question clearly goes beyond decisions about whether or not to throw surprise parties. It touches upon a fundamental question in the psychology of emotions, namely to what extent emotions are characterized by a clear-cut valence. Whereas most other emotions have been associated with such a clear-cut valence—they feel either good or bad—for surprise the case is not clear. Large-scale emotion studies have not found a clear positive or negative valence (see Fontaine, Scherer, Roesch, & Ellsworth, 2007; Russell, 1980) and many classical and contemporary ideas of surprise seem to portray it as a kind of emotional chameleon, feeling sometimes good and sometimes bad depending on whether the cause of the surprise was in itself positive (e.g., a gift) or negative (e.g., a tax assessment).

The unclear valence of surprise has sometimes been explained by viewing it not as an emotion, but rather as a pre-emotional cognitive state. For example, Bain (1859/2006) already stated that: "… there are surprises that delight us, and others that cause suffering; but many surprises do neither" (p. 13). He did not see surprise as a true emotion but rather as a cognitive phenomenon that affects behavior "…by detaining the attention, or by keeping a certain impression in the ascendant" (p. 13). These ideas resonate in some contemporary models of surprise, which position appraisals of unexpectedness and the ensuing interruption of ongoing processes before the analysis of the evaluation of an event (e.g., Meyer, Reisenzein, & Schützwohl, 1997). Thus, Reisenzein and Meyer (2009) concluded that: "in contrast to paradigmatic emotions such as joy or fear, surprise does not presuppose the appraisal of the eliciting event as positive (motive-congruent) or negative (motive-incongruent), and the feeling of surprise is per se hedonically neutral rather than pleasant or unpleasant" (p. 387).

The cognitive view of surprise contrasts with views of surprise as one of the basic emotions (Ekman, 1982). In contrast to Bain, Charles Darwin (1872/1998) saw surprise clearly as an affective state, noting a relationship with fear: "Attention, if sudden and close, graduates into surprise; and this into astonishment; and this into stupefied amazement. The latter frame of mind is closely akin to terror" (p. 278). Darwin observed that many people mentioned seeing terror, horrified, painful, or even disgusted (all distinctly negative emotions) in Duchenne's photographs of a surprised face. These observations were corroborated in later, more systematic studies of facial expressions (e.g., Ekman, 1982). Surprise displays several other characteristics of "regular" emotions such as bodily arousal, a neurophysiological substrate, and an adaptive function (e.g., Breugelmans et al., 2005; Ekman, 1982).

Furthermore, surprise has been fruitfully studied as an emotion in various fields, such as cognitive sciences, economics, marketing, and psychology (e.g., Mellers, Schwartz, Ho, & Ritov, 1997; Schützwohl & Borgstedt, 2005; Valenzuela, Mellers, & Strebel, 2010).

If surprise would indeed be a regular emotion, how should we account for the unclear findings regarding its valence? Many classical models of emotion seem to make the assumption that valence (also labeled evaluation, hedonic tone, or positivity) is a crucial element of what makes an emotion (Barrett, 2012; Barrett, Mesquita, Ochsner, & Gross, 2007; Frijda, 1986; Russell, 2003). Mixed emotions do exist, but these are—as the term implies—co-occurrences of distinct emotions with a singular valence (e.g., Larsen, McGraw, & Cacioppo, 2001). Neutral emotions do not seem to fit these models, but it can of course be questioned whether a neutral valence would theoretically be problematic. If valence is seen as a dimensional property on which emotions take a certain position there is no logical reason why a neutral position would be problematic. The current paper cannot pretend to solve these issues, but rather takes a more pragmatic, explorative position. Given that most emotions that have been described in the literature are experientially characterized by a clear valence, how should we understand the current mixed findings on the valence of experiences of surprise?

This paper explores the idea that experiences of surprise may actually have a negative valence. This idea is based on an integration of models of surprise as an interruption mechanism with a broad literature on how people deal with unexpectedness and violations of predictability.

Surprise can be seen as an interruption mechanism (Meyer et al., 1997); it is elicited by unexpected events, interrupting ongoing thoughts and activities, and motivating people to pay attention to the unexpected stimulus. Such interruptions tend to be not merely cognitive events, but are rather unpleasant. Unexpectedness frustrates people's need for predictability and structure (Abelson et al., 1968; Gawronski & Strack, 2012), which is experienced as threatening and uncomfortable (Elliot & Devine, 1994; Mendes, Blascovich, Hunter, Lickel, & Jost, 2007). For example, a classical study by Aronson and Carlsmith (1962) showed that people experience an uncomfortable dissonance when they are confronted with unexpected good performance. People even tend to prefer self-consistent over self-enhancing feedback in order to bolster their perceptions that reality is predictable and controllable (Swann, 1990). Comparable findings have been found in studies of meaning violating experiences (see Proulx, Inzlicht, & Harmon-Jones, 2012, for an overview) and compensatory control processes that people employ to protect the belief that reality is orderly and nonrandom (see Kay, Whitson, Gaucher, & Galinsky, 2009, for an overview).

The idea that surprise represents a negative interruption is congruent with findings from neuroscientific and psychophysiological studies. Recent models of the medial prefrontal cortex and especially the anterior cingulate cortex in learning and predicting outcomes of actions suggest that negative *as well as positive* surprises result in a prediction error signal (Alexander & Brown, 2011; Egner, 2011). For instance, Error Related Negativity (ERN) has been observed in response to surprising outcomes (see Alexander & Brown, 2011). According to Hajcak and Foti (2008), the ERN can be related to emotional or motivational aspects of error detection and reflects an aversive defensive response. Furthermore, when interacting with an expectancy-violating partner people display physiological threat responses, even when this partner is *positively* surprising (Mendes et al., 2007). Taken together, these findings suggest that at a neural and psychophysiological level, responses to surprise are similar for positive and negative events. In other words, responses to surprise seem to be independent of the valence of the stimulus. Moreover, these findings point to the possibility that surprise has a negative valence.

In view of the long history on studies of surprise and unexpectedness/ inconsistency, it could be asked why a negative valence for surprise has not been suggested before. Part of the answer may be that the emotion literature and the literature on inconsistencies have remained largely separate until now. Another part of the answer may be that the most elaborate and sophisticated research programs on surprise have primarily focused on cognitive processes and consequences and less so on affective consequences (see Reisenzein & Meyer, 2009). However, we think there is a third answer that is of a methodological nature and that is particular to the way surprise has been studied in research that did include measures of emotional valence. Such studies typically employed retrospective and linguistic methods, meaning that participants rated how intensely or frequently they felt surprise (Russell, 1980) or what affective states could be delineated from someone saying that he/she is surprised (Fontaine et al., 2007). Because surprise is a short-lived emotion (Ekman, 1982) it is plausible that episodic memories of surprising events involve a blend of the experience of surprise with that of the emotion that followed after sense-making, being either positive or negative depending on whether the event was goal-conducive or not. Thus, unexpected events initially result in surprise but once the event is understood other affective states follow depending on the nature of the event. The reliance on retrospective and linguistic methods probably resulted in a measure of both responses, producing mixed results. As Tomkins (1984) already noted about surprise: "Whatever its quality (…) it is frequently confused with the affect that immediately follows it" (p. 171). Similarly, the use of emotion words may have led to a particular blurring of the memories of surprise because everyday uses of surprise in phrases such as "throwing a surprise party" and "buying someone a surprise" may have caused the connotation of the word surprise to be biased towards a positive valence.

So, in addition to exploring the idea that surprise may have a negative valence, we will also study a) linguistic biases and b) the temporal dynamics of surprise as possible explanations for why such a negative valence has not been found before. We present three experiments that use a diverse set of methods to explore the valence of surprise. Specifically, we studied autobiographical recall of experiences of unexpected and surprising events in Experiment 2.1, ratings of words and facial expressions in Experiment 2.2, and judgments of naturalistic facial expressions unfolding after surprising events in Experiments 2.3a/2.3b.

Experiment 2.1

Experiment 2.1 studied temporal dynamics in people's autobiographical recalls of surprise. In addition, we explored semantic biases in the emotion word surprise by asking some participants to report an unexpected event and others to report a surprising event. We expected participants to rate their initial experiences as more negative and more surprising than their subsequent experiences.

Method

Participants. A total of 446 people (278 females, 166 males, 2 not reported; M_{age} = 27.78 years, SD_{age} = 14.59) were recruited through snowball sampling by assistants and completed a questionnaire about an *unexpected* event (n = 326) or a *surprising* event (n = 120).

Procedure. Participants described a personal experience of an unexpected or a surprising event. They rated this experience for two separate moments: "Right at the moment that something unexpected/surprising happened" (t1); and "After a short while, when you understood what had happened" (t2). Experiences at both moments were rated on three items that loaded high on Fontaine et al.'s (2007) *unexpectedness* dimension (unpredictable, happened suddenly, was unexpected), three items that loaded high on the *evaluation* dimension (dangerous, pleasant, lost), eight items measuring general *affect* adapted from Elliot and Devine (1994: happy, energetic, uncomfortable, uneasy, calm, optimistic, annoyed, and dejected), and two items measuring *surprise* (surprised and amazed; all ratings on 5-point scales, 1 = *not at all* to 5 = *very strongly*).

Results

Principal Component Analysis (PCA) on the appraisals showed a two-dimensional structure within both conditions (i.e., unexpected and surprising). This was true for measures at t1 (Eigenvalues of the two components: 2.21 and 1.33; 59% variance explained for the unexpected condition and Eigenvalues 2.32 and 1.42; R^2 = 62% for surprising) and at t2 (unexpected Eigenvalues 2.43 and 1.43, R^2 = 64%; surprising Eigenvalues 2.18 and 1.65, R^2 = 64%). On the first component loaded appraisals of suddenness, unpredictability, and unexpectedness. Items were averaged to form the *unexpectedness* index (Cronbach's α at t1 = .67 and at t2 α = .79 in the unexpected condition; t1 α = .78 and t2 α = .74 in the surprising condition), with higher scores signifying more unexpectedness. On the second component loaded appraisals of pleasantness, danger, and loss of control. Items were recoded and averaged to form the *evaluation* index (unexpected t1 α = .59 and t2 α = .60; surprising t1 α = .68 and t2 α = .58), with higher scores indicating a more positive evaluation.

PCA on the affect scale showed a unidimensional structure in both conditions at t1 (unexpected Eigenvalue 3.36 and R^2 = 42%; surprising Eigenvalue 4.22 and R^2 = 53%) and at t2 (unexpected Eigenvalue 3.56 and R^2 = 43%; surprising Eigenvalue 4.33 and R^2 = 54%). Items were recoded and averaged to form the *affect* index (unexpected t1 α = .79 and t2 α = .81; surprising t1 α = .85 and t2 α = .86), with higher scores indicating more positive affect. The emotion items surprised and amazed were significantly correlated both at t1, unexpected r(326) = .49, p < .01, surprised, r(120) = .30, p < .01, and at t2, unexpected r(326) = .67, p < .01, surprised r(120) = .62, p < .01. Items were averaged to form the *surprise* index, with higher scores indicating more surprise.

We performed repeated measures ANOVAs on each of the four dependent measures, with Condition as between-participants factor and Time as within- participants factor. *Evaluation* revealed significant effects of Condition, $F(1, 444) = 141.84$, $p < .001$, $\eta^2 = .24$, and Time, $F(1, 444) = 40.20$, $p < .001$, $\eta^2 = .08$. *Affect* revealed a significant effect of Condition, $F(1, 444) = 162.49$, $p < .001$, $\eta^2 = .27$, of Time, $F(1, 444) = 72.47$, $p < .001$, $\eta^2 = .14$, and a significant interaction, $F(1, 444) = 13.58$, $p < .001$, $\eta^2 = .03$. *Unexpectedness* revealed a significant effect of Time, $F(1,444) = 87.77$, $p < .001$, $\eta^2 = .17$, and *Surprise* revealed significant effects of Condition $F(1, 444) = 12.46$, $p < .001$, $\eta^2 = .03$, and of Time, $F(1, 444) = 251.09$, $p < .001$, $\eta^2 = .36$.

Table 2.1: Mean (and SD) evaluation, affect, unexpectedness, and surprise as a function of Time and Condition (Experiment 2.1).

	unexpected event		surprising event	
	time 1	time 2	time 1	time 2
evaluation	2.80 (1.11)	2.96 (1.07)	4.00 (0.89)	4.25 (0.74)
affect	2.75 (0.89)	3.11 (0.90)	3.96 (0.75)	4.10 (0.69)
unexpectedness	4.04 (0.86)	3.71 (1.04)	4.00 (0.66)	3.57 (0.86)
surprise	4.03 (0.93)	3.36 (1.12)	4.45 (0.58)	3.59 (0.98)

Note: Ratings on a 5-point scale (1= *not at all* to 5 = *very strongly*). Higher ratings indicate more positive evaluation and affect.

As can be seen in Table 2.1, participants in both conditions evaluated their experiences as more negative and also as more unexpected/surprising at *t1* than at *t2*. In addition, participants evaluated their experience as more positive in the Surprise condition than in the Unexpected condition, suggesting a possible semantic bias in the emotion word. This idea was further tested in Experiment 2.2.

Experiment 2.2

Experiment 2.2 studied whether ratings of a surprised face are influenced by the word surprise (cf. Barrett, 2012). If the word surprise has a positive connotation, then adding this emotion word below a surprised face should make evaluation of the surprised face more positive as compared to not adding a word.

Method

Participants. A total of 81 students (42 females, 39 males; M_{age} = 20.36 years, SD_{age} = 2.39) were randomly assigned to one of two conditions: face-without-a-word or face-with-a-word.

Procedure. Participants rated 24 faces taken from Ekman and Friesen (2003; six faces for surprise, fear, sadness, and happiness). Pictures of male and female faces were shown in random order on a computer screen. The face-without-a-word condition showed only the pictures; the face-with-a-word condition also showed the emotion word below the picture. Participants rated for each picture "How does this person feel?" on a 7-point scale from *very negative* (1) to *very positive* (7).

Results

Ratings of faces were collapsed across emotions. Independent samples *t*-tests on the ratings of each emotion revealed a significant difference for surprise. Participants rated the surprise face as significantly more positive in the face-with-a-word-condition (M = 4.25, SD = 0.56) than in the face-without-a-word-condition (M = 3.72, SD = 0.58), $t(79) = -4.21$, $p < .001$. No such differences were found for any other emotions: fear ($M_{without\text{-}word}$ = 2.65, SD = 0.65 versus $M_{with\text{-}word}$ = 2.45, SD = 0.46), $t(79) = 1.56$, $p = .12$; sadness ($M_{without\text{-}word}$ = 2.36, SD = 0.52 versus $M_{with\text{-}word}$ = 2.52, SD = 0.51), $t(79) = -1.37$, $p = .18$; and happiness ($M_{without\text{-}word}$ = 5.94, SD = 0.55 versus $M_{with\text{-}word}$ = 5.91, SD = 0.50), $t(79) = 0.27$, $p = .79$. These results suggest that the emotion word surprise conveys a positive bias to the perception of facial expressions of surprise, which was not found for fear, sadness, and happiness. These findings suggest this specific bias may be unique to or at least more pronounced for surprise (however, see Barrett, 2012).

Experiment 2.3a

Experiment 2.3 studied the unfolding of expressions to unexpected events in TV-shows where people were positively surprised. Following the idea that surprise has a negative valence that—in positive cases—is followed by a positive state, we expected spontaneous expressions to be rated more negatively in the first seconds after a surprise than those in later seconds.

Method

Participants. A total of 119 people (66 females, 53 males; M_{age} = 30.50 years, SD_{age} = 2.50) were recruited to participate in an online study through snowballing on a social network site (*Hyves*).

Procedure. Participants rated stills of eleven faces (randomized order) on 7-point valence scales from *very negative* to *very positive*. Stills were taken from a public website (uitzendinggemist.nl) from two Dutch TV-shows in which people were positively surprised: a garden program (*Tuinruimers*; Festen, 2009, 2010) where gardens are renovated as a surprise and Antiques Roadshow (*Tussen Kunst en Kitsch*; Drion, 2009) where people received high assessments of their antiques. Selection was based on the following criteria: (1) the situation is clearly a positive surprise; (2) people's facial expression is clearly visible for at least four seconds; and (3) the expression is seen from the front. From each episode we took five stills; t0 was the moment at which the person was first confronted with the surprising event; t1-t4 were taken consecutively every second after t0. The resulting 55 stills were distributed over five groups (with t0-t4 randomly distributed) with the constraint that one participant never saw the same face more than once.

Results

Ratings were averaged across participants and episodes in a Still (11) x Time (5) matrix. A repeated measures ANOVA with Time as within-participants factor revealed a significant effect, Wilks' Lambda = .15, $F(4, 7) = 9.76$, $p < .01$, $\eta_p^2 = .85$ (see Table 2.2). Simple contrast analysis showed that faces at t0 and t2 were rated as significantly more negative compared to those at t4 (ps < .05).

Experiment 2.3b

These findings were replicated in a second experiment where an independent sample ($N = 48$; 35 females, $M_{age} = 21.37$ years, $SD_{age} = 2.63$) viewed the same faces to assess the situation that this person was in. They rated the faces on the *evaluation, affect, unexpectedness,* and *surprise* scales from Experiment 2.1 (see Table 2.2).

Table 2.2: Mean (and SD) valence, evaluation, affect, unexpectedness, and surprise of facial expressions as a function of Time (Experiments 2.3a/2.3b).

	Time				
	0	1	2	3	4
Experiment 3a					
valence[1]	3.39[a]	4.00[abc]	3.61[ab]	4.31[bc]	4.37[c]
	(0.89)	(1.15)	(1.35)	(1.41)	(1.35)
Experiment 3b					
evaluation[2]	2.01[a]	2.63[bc]	2.36[ab]	3.00[c]	3.50[d]
	(0.47)	(0.91)	(1.00)	(1.00)	(0.88)
affect[2]	1.92[a]	2.37[ab]	2.24[a]	2.95[bc]	3.42[c]
	(0.50)	(0.87)	(1.05)	(0.97)	(0.88)
unexpected[2]	3.82[a]	3.26[ab]	3.44[a]	2.88[bc]	2.81[c]
	(0.52)	(1.02)	(1.07)	(0.86)	(0.92)
surprise[2]	3.85[a]	3.34[ab]	3.35[abc]	2.97[bc]	2.87[c]
	(0.52)	(0.99)	(1.13)	(0.74)	(0.94)

Note: Means with different superscripts in rows differ significantly at $p < .05$.
[1] Ratings on a 7-point scale (1 = *very negative* to 7 = *very positive*).
[2] Ratings on a 5-point scale (1= *not at all* to 5 = *very strongly*). Higher ratings indicate more positive evaluation and affect.

Ratings were averaged across participants and episodes in a Still (11) x Time (5) matrix. A repeated measures ANOVA with Time as within-participant factor (see Table 2.2) revealed a significant effect of Time on unexpectedness, Wilks' Lambda = .20, $F(4, 7) = 6.98$, $p = .014$, $\eta_p^2 = .80$. Simple contrast analyses showed that participants rated the faces on t0-2 as more unexpected than on t4 (ps < .05). On evaluation, we also found a significant effect of Time, Wilks' Lambda = .13, $F(4,7) = 11.62$, $p = .003$, $\eta_p^2 = .87$. Simple contrast analyses showed that the participants rated the faces on t0-3 as more unpleasant than on t4 (ps $< .05$). Next, on affect, we also found a significant effect of Time, Wilks' Lambda = .15, $F(4, 7) = 10.17$, $p = .005$, $\eta_p^2 = .85$. Simple contrast analyses showed that the participants rated the faces on t0-2 as showing more negative affect than on t4 (ps $< .05$) and t3 marginally more negative than t4 ($p < .08$). Finally, on surprise, we found a significant effect of time, Wilks' Lambda = .29, $F(4, 7) = 4.21$, $p = .048$, $\eta_p^2 = .71$. Simple contrast analyses showed that the participants rated the faces on t0-1 as more surprised than on t4 ($p < .05$).

Thus, in Experiments 2.3a/2.3b, faces were judged as more surprised *and* more negative in the first few seconds and as less surprised and more positively the more time elapsed.

General Discussion

This research explored the valence of surprise. More specifically, we explored the idea that surprise is experienced and perceived in others as a negative emotion, based on reasoning that surprise represents the interruption of ongoing thoughts and activities, which is unpleasant and in conflict with the desire for predictability and structure (Abelson et al., 1968; Gawronski & Strack, 2012). A series of three experiments, using different research methods, provided some initial evidence that surprise may indeed be a (mildly) negative emotion.

Our experiments also suggest why a negative valence for surprise has not been found before. Experiments 2.1 and 2.3a/2.3b suggest that surprise is a short-lived emotion (see also Ekman, 1982), which could lead to experiences of surprise to be confused with emotions that follow it (see also Tomkins, 1984). Experiments 2.1 and 2.2 in addition suggest a positivity bias in the emotion word surprise, further adding to the confusion when using retrospective, linguistic methods. In order to identify the valence of surprise, it seems important to distinguish it from subsequent emotions that emerge when the situation is understood and appraised in terms of goal-conduciveness (i.e., after surprise has dissipated).

While our data are suggestive of a negative valence, surprise was clearly not as strongly negative as for instance sadness or fear (see Experiment 2.2). Though this might have to do with the strength of the experimental manipulation, with more extreme surprises resulting in more negative responses, it seems also plausible that the negativity associated with uncertainty is less intense than that associated with clearly aversive situations (e.g., Proulx et al., 2012). An alternative possibility is that because of the short duration of surprise people are used to interpreting expressions of this emotion more in context than those of happiness, sadness, or fear (see Barrett, 2012).

In addition, the negative valence of surprise does not imply that the experience of a surprising event can never be positive. Once the surprising event is understood people can feel good about it. Interestingly, this also opens the possibility that surprise may contribute to more intense positive experiences through what has been called an emotion-amplification effect. Given that surprise induces arousal (e.g., Fontaine et al., 2007; Russell, 1980), residual arousal may still be present when the surprising event is understood and the emotion surprise has dissipated. Any subsequent emotion, such as joy, may thus arise in a situation where people already are in a state of heightened arousal, which may lead to more intense experiences of this emotion (see Schachter & Singer, 1962; see also Valenzuela et al., 2010). In other words, the residual arousal can become "attached" to the subsequent emotional state, which intensifies it. As such, a surprise visit of a friend may, for instance, result in increased joy as compared to a planned get together. This possibility would be an interesting avenue for further research on surprise.

A final interesting question is how the desire for predictability and structure relates to the fact that people are also curious creatures that actively explore novel, unknown, and unfamiliar things. How do the apparently opposite desires for predictability on the one hand and for interest in discovering new things on the other relate, and what are the consequences for the experience of surprise? The answer may lie in the sequential nature of emotion processes. According to sequential appraisal perspectives (Scherer, 1999) people first respond to the novelty of a situation (i.e., novelty check) after which other appraisals follow. Silvia (2005) argues that because of this sequential nature, surprise comes first but can shift to interest as the situation unfolds: "... it seems likely that the novelty check precedes the coping potential check, because people must identify a disruption in processing before assessing their ability to comprehend the source of the disruption (p. 99)." In other words, experiences of surprise, driven by the first appraisal of novelty, could shift following a subsequent appraisal of coping potential (see also Gendolla & Koller, 2001). Similarly, when people actively search for novelty (rather than being confronted with it) they probably do this when they think they are able to cope with is. Interestingly, this probably involves an element of anticipating the unexpected and the unknown; the "expected unexpected" can be exciting and interesting but this is probably less surprising than events that were not anticipated at all.

In conclusion, the finding that surprise has a negative valence may further our understanding of how people experience consistencies and inconsistencies in the world around them. With this, we can give a tentative answer to our opening question on whether surprising a loved one is a tragic mistake: it is probably not, but don't expect a happy face or outright gratitude before the person had some time to make sense of the situation.

CHAPTER 3

Surprise: unfolding of facial expressions

This chapter is based on: Noordewier, M. K., & Van Dijk, E. (2016). Surprise: unfolding of facial expressions. *Manuscript submitted for publication.*

Acknowledgements: Thanks to Anne-Linn Beekhof and Frederique Arntz for manually coding the faces. Thanks to Carlo Konings for his help with programming the studies and converting the data. Thanks to Suzanne Kuiper for her help with editing the videos. Thanks to Peter Lewinski for his advice on FaceReader.

Surprise: Unfolding of Facial Expressions

When people are confronted with unexpected, inconsistent, or disfluent stimuli, they experience surprise (e.g., Meyer, Niepel, Rudolph, & Schützwohl, 1991; Meyer, Reisenzein, & Schützwohl, 1997; Noordewier & Breugelmans, 2013; Noordewier, Topolinski, & Van Dijk, 2015; Reisenzein, 2000b). When surprised, ongoing thoughts and activities are interrupted and attention is directed at the surprising stimulus to make sense of it (e.g., Camras et al., 2002; Horstmann, 2006; Meyer et al., 1991, 1997; Reisenzein, 2000b; Scherer, 2001). After sense-making, surprise dissipates and other affective states follow depending on the nature of the surprising event (e.g., Ekman, 2003; Noordewier & Breugelmans, 2013; Tomkins, 1984).

Responses to a surprising stimulus are thus dynamic and unfold from initial interruption (i.e., responses to the unexpectedness of the event) to cognitive mastering (i.e., responses to the valence of the event; Meyer et al., 1991, 1997; Noordewier & Breugelmans, 2013; Noordewier et al., 2015). Therefore, to study surprise rather than its consequences, it is key to take the temporal dynamics of sense-making into account (cf. Noordewier et al., 2015; see also Noordewier & Breugelmans, 2013; Tomkins, 1984). We aimed to do exactly this and systematically tested the temporal unfolding of facial expressions in response to surprising stimuli, to distinguish surprise from the state that follows it. Moreover, we aimed to provide more insight into what surprise expression looks like and what this might mean in terms of the valence of surprise.

Facial expressions are particularly suited to reveal the unfolding of responses, because they can capture initial responses to a surprising stimulus as well as changes in responses over time (cf. Noordewier et al., 2015). In a first study on this, expressions of people who were positively surprised in TV-shows were analyzed (Noordewier & Breugelmans, 2013). Screenshots taken right after the surprise and subsequently at one-second intervals were evaluated in terms of feelings and type of situation the person in the picture was in. Faces were more negative in the first moments as compared to later; a pattern that was assumed to reflect unfolding of responses, from interruption to mastering (Noordewier & Breugelmans, 2013).

In line with this, a facial electromyography study (fEMG; Reisenzein et al., 2006, Study 7) showed that participants who were surprised with an unanticipated photograph of themselves had a slight increase of corrugator activity (i.e., frown; also found in Topolinski & Stack, 2015; see also Schützwohl & Reisenzein, 2012), which was after 1-3 seconds followed by an increase in zygomaticus activity (i.e., smile). While in this study Reisenzein et al. aimed to test the occurrence of the surprise expression (raised eyebrows, eye-widening, jaw drop; Darwin, 1872/1998; Ekman, Friesen, & Hager, 2002) rather than its temporal dynamics per se, it supports the notion that initial responses to surprising stimuli differ from later responses. Interestingly, these studies also point to two other elements of the responses to surprise stimuli: The initial expression is more negative than the later expression and it may involve frowning.

First, regarding the valence of the expression, several lines of work indeed support the notion that surprise or interruption is relatively negative (see also Hajcak, 2012; Mendes et al., 2007; Miceli & Castelfranchi, 2015; Noordewier & Breugelmans, 2013; Topolinski & Strack, 2015). In fact, from the point of view of cognitive consistency theories and personal control perspectives, surprise reflects inconsistency, disruption, and lacking of structure. Because this conflicts with people's need for a predictable and coherent world, this may feel relatively negative (Abelson et al., 1968; Gawronski & Strack, 2012; Kay, Whitson, Gaucher, & Galinsky, 2009; Miceli & Castelfranchi, 2015; Proulx, Inzlicht, & Harmon-Jones, 2012; Rutjens, Van Harreveld, Van der Pligt, Kreemers, & Noordewier, 2013).

So, even if the surprising stimulus is positive, people first experience this brief phase of inconsistency and lack of meaning (i.e., surprise), before they can appreciate the outcome as is it (i.e., the state after surprise). Importantly, this means that to understand surprise, it should not be confused with its consequences and only by taking time into account, surprise can be distinguished as initial interruption from subsequent states that follow after sense-making. This temporal dynamics perspective also explains why other researchers suggested that surprise feels positive (e.g., Fontaine et al., 2007; Mellers, Schwartz, Ho, & Ritov, 1997; Valenzuela, Strebel, & Mellers, 2010), as they measure retrospective evaluations or feelings *after* cognitive mastering (see Noordewier et al., 2015, for a similar reasoning).

Second, the expression after a surprise might thus involve frowning (Topolinski & Strack, 2015; see also Reisenzein et al., 2006;

Schützwohl & Reisenzein, 2012). This seems inconsistent with the "typical" surprise expression (raised eyebrows, eye-widening, jaw drop). Previous research already showed, however, that this "typical" expression is in fact rarely and only partly observed in a minority of surprised people (mostly raising eyebrows only; 4-25% in Reisenzein et al., 2006; 34% in Reisenzein, 2000; 10-33% in Schützwohl & Reisenzein, 2012). Yet, it should be noted that in these studies it is not always clear whether participants who did not show a surprised face showed a neutral face or other facial action. Besides frowns, smiles were also observed (2-86% in Reisenzein et al., 2006; 26-71% in Schützwohl & Reisenzein, 2012; 8.6-12.1% in Scherer, Zenter, & Stern, 2002); and in infant studies, freezing (Camras et al., 2002; Scherer et al., 2002) and signs of interest were also found (Camras et al., 2002).

There is thus some indication that the expression after a surprise involves frowning, yet other facial action has also been observed. Importantly, because most studies did not take time into account, the possibility that different facial actions follow each other remains untested. To better understand the expression after a surprise, it is therefore important to incorporate time when coding different facial actions.

The Current Studies

To clarify the temporal unfolding of facial expressions in response to a surprising stimulus, we developed two repetition-change studies—a standardized and well-validated procedure to induce surprise (e.g., Camras et al., 2002; Meyer et al., 1997; Reisenzein et al., 2006). We tested our predictions using positive surprises (Experiments 3.1 and

3.2) as well as a negative surprise (Experiment 3.2) and recorded facial expressions using webcams. Using computerized and manual coding, we measured the valence of facial expression over time as well as different facial action elements.

We predict that if surprise is relatively negative and different from subsequent states after sense-making, 1) initial expressions to positive surprises are more negative than later expressions and 2) responses to positive and negative surprises are initially similar and only start to differentiate depending on the nature of the event after some time. We report all manipulations, all measures, and all data exclusions. Sample sizes are at least 50 per cell (Simmons, Nelson, & Simonsohn, 2011, 2013), yet, we collected more data to be able to account for data exclusion as a result of coding errors and participants not giving permission to use their material.

Experiment 3.1: A Surprising Puppy

In the first study, we tested our unfolding hypothesis by positively surprising participants with a puppy.

Method

A total of 71 participants (47 females, 24 males; M_{age} = 22.32 years, SD_{age} = 4.87) were assigned to a within participants design in which we compared facial expressions in response to neutral stimuli (baseline) and to a positive surprising target.

Procedure and Materials. The study started with a cover story to explain the use of the webcam and to induce a social context. Participants were told that they would participate in a study on eyemovement and attention to pictures and in order to analyze their eye-movements, we would record them with a webcam. Then, we wanted to make the context somewhat more social than the more typical lab setting, where participants are in a lab cubicle on their own. A pilot test showed that participants were not very expressive in this setting and we reasoned that one explanation could be that it is not social enough (e.g., Friedlund, 1991). Therefore, we told participants that recent research suggested that there are reasons to believe that people perform better on attention tasks when they do this with other people and that we were interested to test whether it is necessary to see the other person or not. We told them that they would be connected to another participant via the webcam, like on Skype. This story was most likely extra credible to participants, as in the two preceding, but unrelated, experiments in the experimental session they were also connected to other participants (in one experiment for real, in the other also as part of a cover story). They were then presented with a pre-recorded video of a confederate with the request to look at the other person and to connect with this person by for instance waving. The confederate waved and on the footage, we saw many participants doing so too, which leads us to believe that we created a credible social context. A picture (i.e., a still frame) of the confederate remained in the top right corner of the screen throughout the neutral part of the experiment.

After instructions, participants continued to the main part of the experiment in which they were surprised. Surprise was induced using a repetition-change procedure. On a computer screen participants were presented with a series of trials with sequential presentation of affectively neutral stimuli: buildings. Each trial presented four pictures of buildings (i.e., building-building-building-building) at one-second intervals and ended with a question asking participants to indicate whether the last picture in the trial contained any green. On a keyboard, they could press either "a" or "l", for yes and no, respectively. Participants were given one second to press the key. So, all elements in the trials took one second, which gave each trial a certain rhythm, which strengthens the expectancy of what will follow (buildings and a question).

After four practice trials, fourteen experimental trials followed. The last trial was the critical surprise trial. In this trial, instead of presenting participants with the question, we showed them a gif-file of a puppy, in which the puppy moved its head and paw towards the camera (see imgfave.com/view/1494654). The gif repeated three times, which took 9 seconds in total. After the surprise trial, the experiment automatically continued to some background questions. Participants were asked to indicate (translated from the original Dutch) "To what extent were you surprised by the puppy?" (from 1 = *not at all* to 7 = *extremely*) and "What did you think of the puppy?" (from 1 = *negative* to 7 = *positive*). Then we asked them to report their age and gender and whether they participated before in a comparable study before (yes/no; we ran a pilot study a couple of months before this study). Finally, participants were fully debriefed and they were asked for permission to use their recorded footage (yes/no).

Results and Discussion

The analyses consisted of different steps. First, we selected participants. Then, we checked our manipulation. Finally, after editing the footage, we tested our unfolding predictions by analyzing the footage in two ways. First, the facial expressions were coded using Noldus' FaceReader (version 5; see Noldus.com/FaceReader). Next, the facial expressions were also coded manually (see below).

Participant Selection, Target Evaluation, Footage Editing. We excluded participants who did not give permission to use their footage (N = 8) and who participated before in a similar (pilot) study (N = 2). Next, we excluded participants who wore glasses (N = 8; glasses may hinder classification in FaceReader; Noldus, 2012, p. 16) and those who resulted in other coding errors (N = 1, extreme yawning). We analyzed the data of the remaining 52 participants (18 males, 34 females; M_{age} = 21.83 years, SD_{age} = 4.79). We first checked the ratings of the target. As expected, the target was rated as relatively surprising (M = 6.00, SD = 1.12) and as relatively positive (M = 5.85, SD = 1.36).

Next, we edited the videos such that they started two seconds before display of the surprising stimulus (baseline) until eight second after the surprise. We did this based on event markers that were saved during the experiment: We saved the start and stop time of the experiment and we saved the time of critical trials. Based on the total duration of the video, we could then calculate for each participant separately when the surprising event took place. We then converted each video such that they were chronologically similar and as such, comparable in the analyses. Then, we analyzed the footage in FaceReader and using manual coding.

FaceReader. After uploading videos, FaceReader can analyse facial expressions in terms of basic emotions (i.e., happiness, sadness, anger, surprise, fear, and disgust) and general valence (happiness minus negative emotions, excluding surprise). FaceReader first locates the face and then creates a face model based on 500 key points. The face is then compared to a database of 10,000 manually coded faces. The deviation of the face relative to database is made and intensity of expressions calculated. For each frame, FaceReader computes intensity scores for expressions of basic emotions (0 to 1) and valence (-1 to 1; for more information, see noldus.com/facereader; for validation see Den Uyl & Van Kuilenburg, 2005; Van Kuilenburg, Wiering, & Den Uyl, 2005; Lewinski, Den Uyl, & Butler, 2014; for studies using FaceReader see e.g., Chentsova-Dutton & Tsai, 2010; Garcia-Burgos & Zamora, 2013).

The FaceReader data allowed us to compare the unfolding of responses within participants; comparing expressions before, during, and after the surprise. We focused on two output measures: *valence* and *surprise*. FaceReader was set to analyze 25 frames per second and to calibrate each participant individually, filtering out person-specific biases (e.g., looking angry or happy by nature). We reduced this large data set (i.e., 250 data points per participant for both valence and surprise) by computing an average intensity score on valence and surprise for each 0.5-second (mean of 12 or 13 frames) for each participant. After restructuring the data, the final data consisted of 21 data points (resulting in the within participants factor Time) for each participant for both valence and surprise on which we ran repeated measures ANOVAs. In all analyses (also Experiment 3.2), we performed Greenhouse-Geisser corrections where necessary (visible in adjusted degrees of freedom). Note that when we refer to seconds, the negative numbers refer to seconds before the surprising stimulus (i.e., baseline) and the positive numbers refer to seconds after the surprising stimulus.

Figure 3.1: Valence of facial expression in response to a surprising puppy as a function of Time (Experiment 3.1).

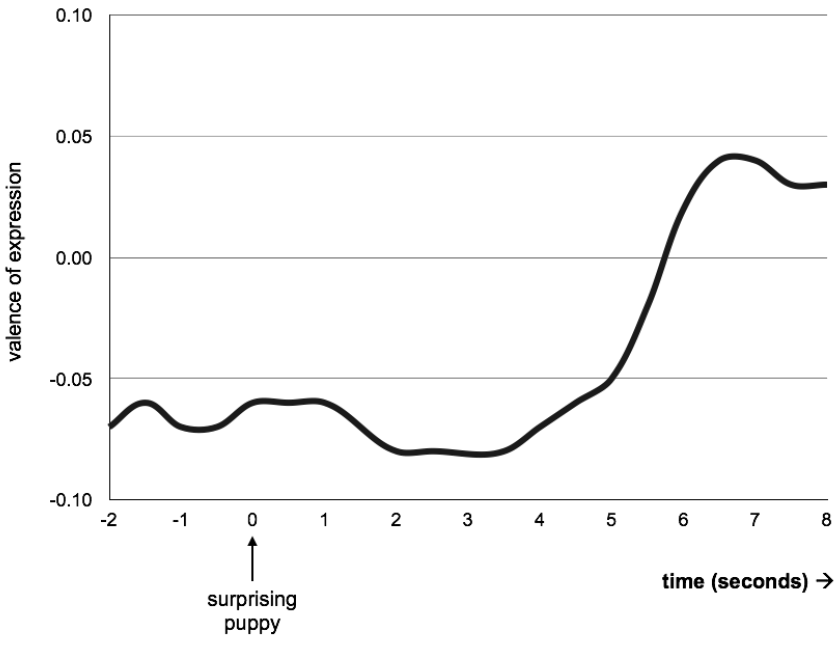
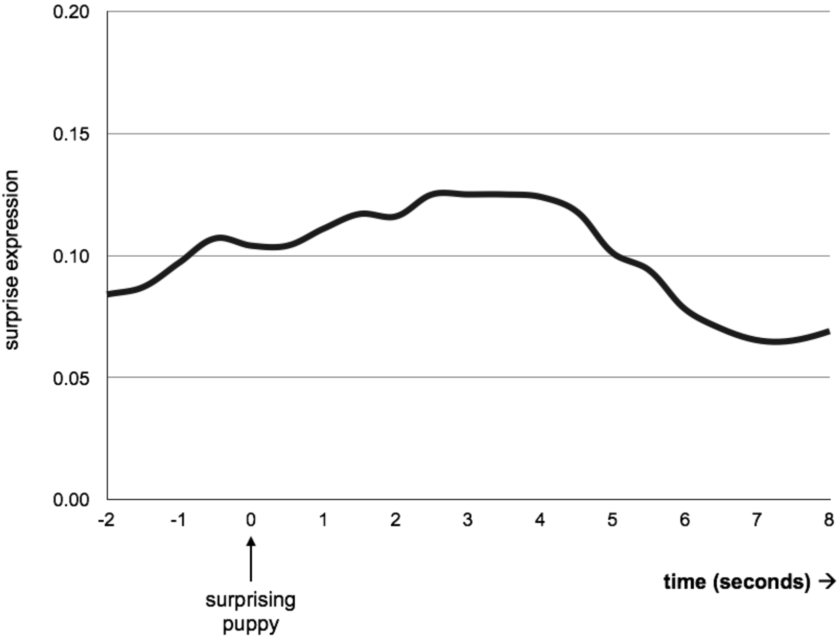


Figure 3.2: Surprise expression in response to a surprising puppy as a function of Time (Experiment 3.1).



Valence. The repeated measures ANOVA (N = 51[5]) showed an effect of Time on valence of expressions, $F(1.66, 83.15) = 4.14$, p = .026, $\eta_p^2 = .08$ (see Figure 3.1). When comparing the valence of expressions relative to baseline (second -2) with within subjects contrasts, we found that expressions were more positive at second 6 until second 8, Fs(1, 50) = 5.16-5.94, ps = .018-.028, η_p^2s = .09-.11.

[5] The number of participants in the analyses is reported when, as a consequence of missing data, it deviates from the total number (i.e., a repeated measures ANOVA and Cochran's Q analyses excludes participants when there are missing data).

Expressions were marginally more positive at second 5.5, $F(1, 50) = 3.03$, $p = .088$, $\eta_p^2 = .06$.

Surprise. The repeated measures ANOVA ($N = 51$) showed a marginal effect of Time on the surprise expression, $F(3.41, 170.72) = 2.47$, $p = .056$, $\eta_p^2 = .05$ (see Figure 3.2). Comparing surprise expressions relative to baseline (second -2) with within subjects contrasts showed marginally more surprise at second 2.5 until 4, Fs(1, 50) = 2.84-3.03, ps = .088-.098, η_p^2s = .05-.06.

In sum, the results show that it takes time to respond positively to a positive surprise and before that, people show some surprise expressions. While there thus seems to be some surprise expression, this is not very strong and the question remains what the facial expression after a surprising stimulus looks like. In Figure 3.1, there is a small decline visible in valence of expression just after the surprise. This decline is not statistically different compared to baseline. Yet, we considered the possibility that expressions are too subtle for FaceReader to detect. We therefore decided to also manually code different facial expressions elements.

Manual Coding. Two independent coders who were blind to the research question and hypotheses of the study were trained using material of a pilot study to code different expression elements. Then, we created screenshots of the 52 videos of the current study at 0.5-second intervals. Each screenshot was coded in terms of absence or presence of a frown, smile, eyebrow raise, jaw drop, and eye-widening. A screenshot was coded a “0” when an element was absent and it was coded on a scale from 1 (*very weak*) to 5 (*very strong*) when an element was present.[6] We also included the option "unclear", which we treated as missing data (0.004% of a total of 12,480 codings).

The interraterreliability of the data was calculated with correlations and because this was not consistently above $r = .70$ (particularly with brow raise, eye-widening), we recoded the data in terms of absence (0) and presence (1 = 1 to 5 intensity score) of the expressions after surprise (comparable absence/presence coding has also been used in Reisenzein et al., 2006). This recoding was done after one coder individually checked her ratings and corrected 0.05% of the brow raise and frown codings. To check reliability, we calculated percentage agreement between coders. Reliability for frown, smile, brow raise, and jaw drop was good, as it ranged between 70% and 100% (except for brow raise on seconds 0-1 and 2-3.5, where it was between 67-69%). The eye-widening agreement was too low (between 48-63%) and therefore excluded from further analyses. Finally, disagreement on all screenshots after the surprising stimulus was solved through discussion and we analyzed these 100% agreement data. Then, we tested whether Time affected the frequency of each expression element with Cochran's Q tests (see Figure 3.3). When an effect was found, we subsequently

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[6] Valence was also coded ("How does this person feel?" on a scale from -2 *negative* to +2 *positive*, with 0 representing neutral). Results replicated the FaceReader data pattern, such that a repeated measures ANOVA showed a main effect of Time, $F(1.68, 85.83) = 11.89$, $p < .001$, $\eta_p^2 = .19$. Relative to baseline (second -2), expressions were coded more positive after second 4 until second 8, Fs(1, 51) = 4.04-17.68, ps = .000-.050, η_p^2s = .07-.26. However, because the correlations between the ratings of the two coders were not consistently high (i.e., they ranged between .26 and .85, with 66% < .70), we excluded these results from the main analyses.

compared individual seconds with McNemar tests. Note that we now only focus on what happens after surprise (baseline is excluded).

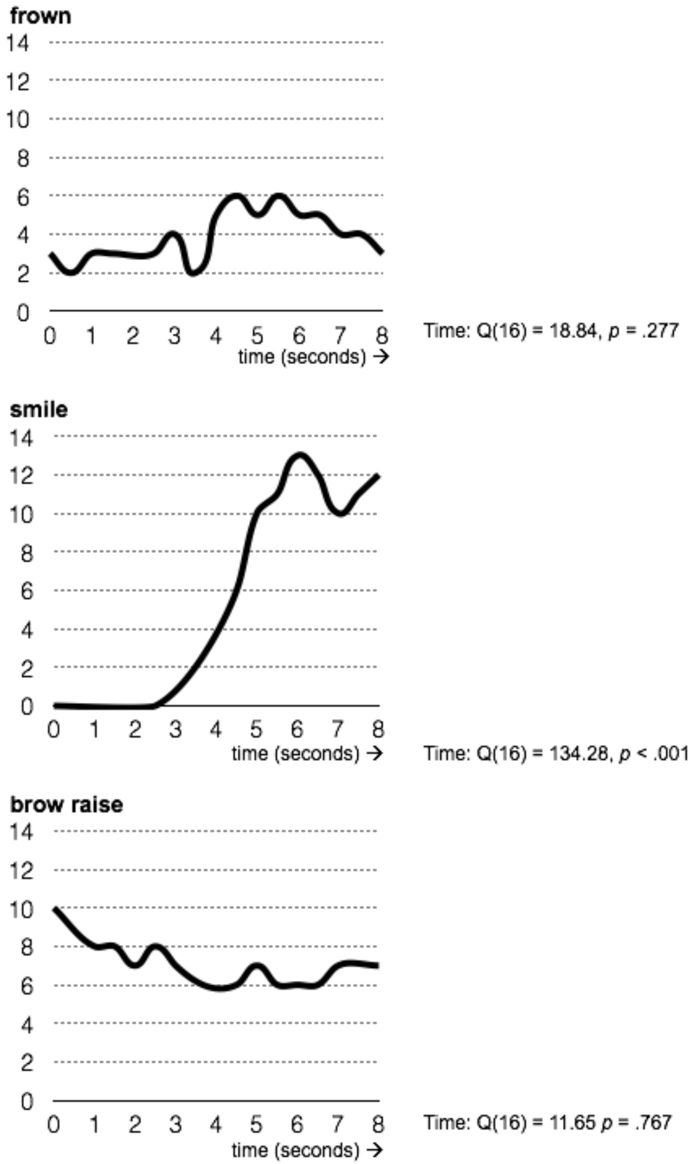
Frown. There was no effect of Time on the number of frowns, $Q(16) = 18.84$, $p = .277$ ($N = 51$).

Smile. There was an effect Time on the number of smiles, $Q(16) = 134.28$, $p < .001$. McNemar comparisons showed that, relative to second 0, there were more smiles from second 4.5 until second 8, *p*s between < .001 and .031, whereas before that, the number of smiles did not differ, *p*s > .124.

Surprise elements. There was no effect of Time on number of brow raises, $Q(16) = 11.65$, $p = .767$ ($N = 50$). There was also no effect of Time on jaw drops, $Q(16) = 12.00$, $p = .744$, which were hardly observed (2 times or less; note that eye-widening was excluded from the analyses; see above).

Taken together, these results show that it takes time to respond positively to a positive surprise. This positivity seems to be characterized by an increase in smiles. In addition, while FaceReader showed some indication of surprise expressions in the first couple of seconds, the manual coding of the separate facial actions did not confirm this result. The second study aimed to induce more intense expressions and also includes a negative surprise.

Figure 3.3: Number of frowns, smiles, and brow raises in response to a surprising puppy as a function of Time (Experiment 3.1).



Experiment 3.2: A Surprising Person

Experiment 3.2 tests the unfolding logic by surprising people in a person-perception setting. We assumed that this setting is more social and self-relevant than the buildings and puppy in Experiment 3.1, which might intensify responses. We again used a repetition-change method and showed participants a series of neutral faces, followed by a face that deviated from the preceding faces and thus was unexpected. This was either a positive or a negative face and as such, we now also included negative surprise condition, which allows us to compare unfolding of responses to surprise to responses to a positive vs. a negative target.

Method

A total of 128 participants (69 females, 59 males; M_{age} = 21.20 years, SD_{age} = 2.25) were randomly assigned to a positive versus negative surprise condition. The study was presented as a test of factors driving first impressions of unknown others. To this end, they were asked to evaluate pictures 20 faces. Pictures were selected from de Radboud Faces Database (RAFD; Langner, Dotsch, Bijlstra, Wigboldus, Hawk, & Van Knippenberg, 2010). We selected equal numbers of males and females, all showing a neutral expression. Each neutral face was shown five seconds after which the question "What is your impression of this person?" appeared on the screen. Participants could answer "positive" or "negative" with respectively green and blue response buttons (i.e., the left and right ctrl buttons on a keyboard were covered with green and blue stickers).

After 20 trials the critical surprise trial showed either a positive or a negative target face for eight seconds. The positive target was a woman with a pig nose mask showing a funny face. The negative target was a man with wounds on his face. Both targets did not show any positive or a negative expression, to prevent that participants would mimic this expression. After the critical trial, the program automatically continued to background questions. Participants were asked to report to what extent they were surprised by the target (from 1 = *not at all* to 7 = *extremely*), to evaluate the target (from 1 = *negative* to 7 = *positive*), and to report their age and gender. Finally, they were fully debriefed and asked for permission to use their footage (yes/no).

Results and Discussion

The analyses were done following the same steps as in Experiment 3.1.

Participant Selection and Footage Editing. First, we excluded participants who did not give us permission to use the footage (N = 5), who wore glasses (N = 8) or because of other coding errors (i.e., N = 2; video could not open and N = 1; only half of the face was recorded). We report analyses of the remaining 112 participants (53 males, 59 females, M_{age} = 21.14 years, SD_{age} = 2.27).

First, we checked the ratings of the target. As expected, the positive target was rated more positive (M = 5.70, SD = 1.69) than the negative target (M = 2.60, SD = 1.26), $t(110)$ = 10.89, p < .001, d = 2.08. Yet, the positive target was rated as equally surprising (M = 5.72, SD = 1.38) as the negative target (M = 6.02, SD = 1.18), $t(110)$ = -1.24,

p = .22, d = -0.23. So, based on this we conclude that our stimuli represented a positive versus a negative surprise.

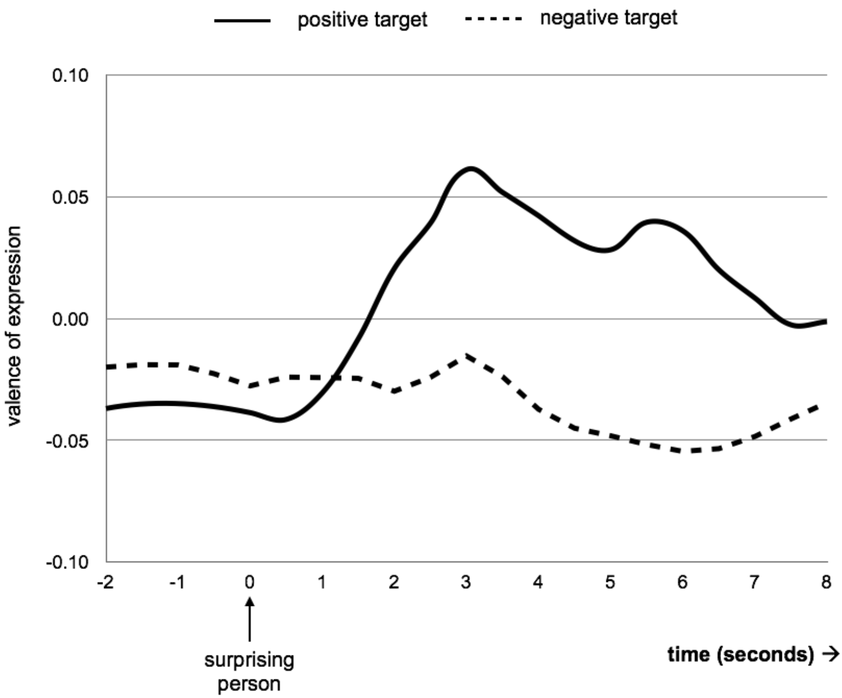
Next, we edited the videos in the same way as in Experiment 3.1, such that they showed participant two seconds before the surprise (baseline) and eight seconds after the surprise. This footage was first coded with FaceReader.

FaceReader. FaceReader was set to analyze 30 frames per second and to calibrate each participant individually, filtering out person-specific biases. We again computed an average intensity score on *valence* and *surprise* for each 0.5-second. After restructuring, the final data had 21 data points (Time) for each participant on valence and surprise on which we ran repeated measures ANOVAs (see Figure 3.4), followed by within subjects contrasts (Time) and between condition comparisons (Target).

Valence. The repeated measures ANOVA showed a main effect of Time on valence of expressions, $F(3.07, 337.43) = 2.59$, $p = .051$, $\eta_p^2 = .02$, and a Time x Target interaction, $F(3.07, 337.43) = 4.76$, $p = .003$, $\eta_p^2 = .04$. To interpret the interaction, we compared the effect of Time within the positive and negative target condition separately.

Within the positive target condition, there was a main effect of Time, $F(2.84, 159.89) = 4.55$, $p = .005$, $\eta_p^2 = .07$. Simple contrasts showed that expressions were more positive relative to baseline from second 1.5 until second 7: Fs between 3.97 and 9.34, ps between .003 and .051, η_p^2s between .06 and .14, and marginally more positive at second 8, $F(1,59) = 3.16$, $p = .081$, $\eta_p^2 = .05$. Within the negative target condition, there was a marginal main effect of Time, $F(2.63, 134.05) = 2.18$, $p = .102$, $\eta_p^2 = .04$. Simple contrasts showed that expressions were more negative relative to baseline from second 4.5 until 7.5, *F*s between 3.89 and 5.38, *p*s between .024 and .054, η_p^2s between .07 and 95.

Figure 3.4: Valence of facial expression in response as a function of Target (positive vs. negative) and Time (Experiment 3.2).



So, facial expressions were initially similar in the positive and negative target condition. Over time, they unfolded to more positive expressions in the positive target condition and to more negative expressions in the negative target condition. Interestingly, expressions seemed to unfold slower in the negative as compared to the positive target condition. Moreover, overall, the unfolding seemed faster than in Experiment 3.1. We will discuss this in more detail in the General Discussion.

Next, we compared the valence of expressions between the two target conditions. Two seconds after the surprise, facial expressions started to differentiate, such that at seconds 2-3.5, expressions in the positive target condition became (marginally) more positive than in the negative target condition, *t*s between 1.80 and 1.98 *p*s between .051 and .068, *d*s between 0.34 and 0.38. From second 4 until 7, conditions differed statistically, such that *t*s were between 2.08 and 2.69, and *p*s between .006 and .026, *d*s between 0.42 and 0.52.

Surprise. No effects were observed on the surprise expression (all *F*s < 1; all means ranged between 0.03 and 0.07).

Manual Coding. We also coded the videos manually in the same way as in Experiment 3.1 (same coders, same method, including recoding in terms of 0 = absence and 1 = presence). We made screenshots at 0.5-second intervals of all 112 videos. These screenshots were coded in terms of frown, smile, brow raise, jaw drop, and eye-widening. The "unclear" option was also included, which resulted in 0.003% missing of a total of 26,880 codings.

Agreement ranged between 70% and 100% (with the exception of frowning on seconds 0.5/1, where it was 65/69%; and eye-widening on seconds 1.5/3 where it was 69/68%, respectively) and disagreement was solved through discussion. Then, we compared the frequency of each expression element between conditions with Chi-square tests.

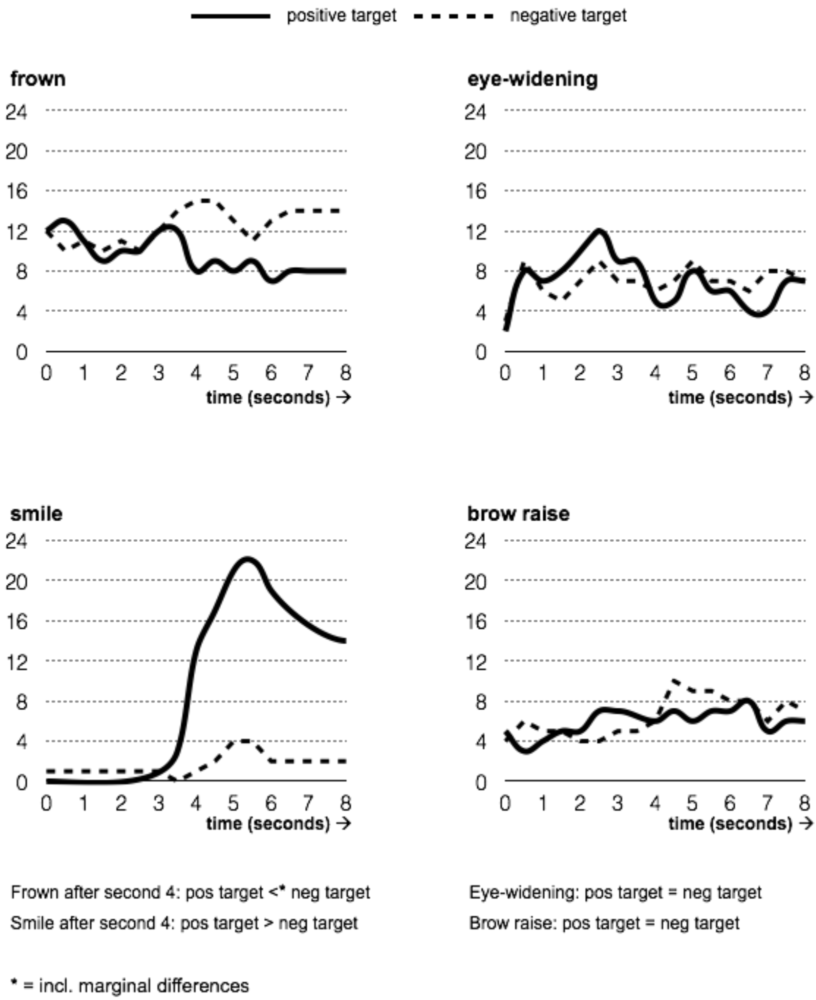
Next, we tested whether Time affected the frequency of each expression element (within each conditions, where relevant) with Cochran's Q tests (see Figure 3.5). When an effect of Time was found, we subsequently compared individual seconds with McNemar tests[7].

Frown. Chi-square tests showed that there were (marginally) fewer frowns in positive target condition than the negative target condition from second 4 until second 8, χ^2s(1, *N* = 107-111) between 2.83 and 4.16, *p*s between .041 and .092, except second 5 and 5.5, χ^2s(1) = 2.69/0.66, *p*s = .101/.415. Before second 4, equal number of frowns were observed in the positive and negative target condition, χ^2s < .68 and *p*s > .40. Within the positive target condition, we found and effect of Time on the number of frowns, *Q*(16) = 35.38, *p* = .004 (*N* = 51). McNemar tests within the positive target condition showed that relative to second 0, the number of frowns did not differ, *p*s > .288, but there were (marginally) fewer frowns relative to second 0.5 at second 6 and 6.5, *p*s = .031/.063 (other comparisons relative to second 0.5, *p*s > .124). Within the negative target condition, there was no effect of Time, *Q*(16) = 16.46, *p* = .421 (*N* = 49). So, initially, we observed the same

[7] Similar to Experiment 3.1, valence of expressions was coded as well and results replicated the FaceReader data pattern, even though interraterreliability was not consistently high (correlations ranged between .32 and .83 with 62% < .7). A repeated measures ANOVA (*N* = 110) on the averaged ratings of both coders showed a Time x Target interaction, *F*(2.12, 228.65) = 15.94, *p* < .001, η_p^2 = .13, and a main effect of Time, *F*(2.12, 228,65) = 16.04, *p* < .001, η_p^2 = .13. Within the positive target condition, the expressions were more positive relative to baseline (second -2), after second 3 until second 8, *Fs*(1, 50) = 6.32-37.86, *p*s = .000-.015, η_p^2s = .10-.40. Within the negative target condition, the expressions did not change over time, *p*s > .558. Comparing positive and negative target conditions, we see that the facial expressions start to differ from second 4 until second 8, *t*s(110) = 3.10-3.75, *p*s < .003, *d*s > 0.59.

amount of frowning in both conditions. Over time there was (marginally) less frowning in the positive target condition as compared to the negative target condition.

Figure 3.5: Number of frowns, smiles, eye-widenings, and brow raises as a function of Target (positive vs. negative) and Time (Experiment 3.2).



Smile. Chi-square tests showed that there were more smiles in the positive target condition than the negative target condition from second 4 until second 8, χ^2s(1, *N* = 111-112) between 8.86 and 14.15, *p*s between < .001 and .003, and marignally more on second 3.5, χ^2(1, *N* = 111) = 2.72, *p* = .099. Before second 3.5, equal number of smiles were observed in the positive and negative target condition, χ^2s (1, *N* = 111-112) < 1.17 and *p*s > .280. Within the positive target condition, we found an effect of Time on the number of smiles, *Q*(16) = 202.16, *p* < .001. McNemar tests within the positive target condition showed that, relative to second 0, there were more smiles from second 4 until second 8, *p*s < .001, whereas before that, the number of smiles did not differ, *p*s > .249. Within the negative target condition, there was no effect of Time, *Q*(16) = 15.39, *p* = .496. So, initially, there were hardly any smiles in both conditions and over time this unfolded to more smiling in the positive target condition, but remained equally low in the negative target condition.

Surprise elements. Chi-square tests showed that conditions did not differ in number of brow raises, χ^2s (1, *N* = 108-111) < 1.69, *p*s > .192, or jaw drops (between 3 and 7 times observed), χ^2s (1, *N* = 111-112) < 1.01, *p*s > .316, or eye-widening, χ^2s (1, *N* = 109-112) < 2.21, *p*s > .136. Next, we tested the overall effect of Time, which showed that Time did not affect the number of brow raises, *Q*(16) = 15.32, *p* = .501 (*N* = 106), or jaw drops, *Q*(16) = 11.12, *p* = .802 (*N* = 109). There was, however, an effect of Time on eye-widening, *Q*(16) = 27.42, *p* = .037

(N = 107). Relative to second 0, there was more eye-widening from second 0.5 until second 8, *p*s between < .001 and .092, except on second 4 and 6.5, *p*s > .145.

Taken together, these results support our unfolding logic. Initially, responses to a positive or a negative surprise did not differ. Over time, expressions to a positive target became more positive, whereas to a negative target they stayed the same. Moreover, initially, there were equal numbers of frowns in both conditions, whereas later, there were less frowns and more smiles in the positive as compared to the negative target condition.

General Discussion

Responses to a surprising stimulus are dynamic and unfold from initial interruption to cognitive mastering of the event (Meyer et al., 1991, 1997; Noordewier & Breugelmans, 2013; Noordewier et al., 2015). To study surprise and distinguish it from the state that follows it, we tested the temporal unfolding of facial expression in response to a surprising stimulus. Results of two repetition-change studies showed that initial expressions after positive surprises are more negative than later expressions. Moreover, expressions after a positive and negative surprise are initially similar and only after some time start to differentiate, depending on the valence of the event. Finally, irrespective of the valence of the surprise, participants showed initially equal number of frowns (Experiment 3.2), which only later turned to smiles when the outcome was positive (Experiments 3.1 and 3.2). Taken together, these results confirmed the notion that responses to surprising stimuli unfold from responses to the unexpectedness of the event to the valence of the event (see also Meyer et al., 1997; Noordewier & Breugelmans, 2013; Noordewier et al., 2015).

Interestingly, when we compare the two studies in terms of speed of unfolding, it becomes clear that expressions unfolded much faster in the study with the surprising faces than the study with the surprising puppy (see Figures 3.1 and 3.4). The relation between expectancy and surprise is a plausible explanation for this difference. The surprising puppy in Experiment 3.1 was categorically different from the preceding repetition trials (buildings), whereas the surprising positive/negative faces in Experiment 3.2 were categorically similar to the preceding repetition trials (neutral faces). Categorical similarity of surprise to the preceding context may make the surprise easier to categorize, which facilitates sense-making and thus, faster responses to the actual meaning of the target. Moreover, faces are probably more self-relevant to participants than a puppy, which could have contributed further to faster unfolding.

Besides showing unfolding of responses after a surprising stimulus, we also aimed to get more insight into what the expression after a surprise looks like. Previous research already showed that the typical surprise expression with raised eyebrows, eye-widening, and jaw drop is rare (Reisenzein et al., 2006) and that people might initially frown (Topolinksi & Strack, 2015). We find some (marginal) evidence for initial frowning and later eye-widening (Experiment 3.2). Importantly, in line with our unfolding logic, frowns were initially equally strong for both the positive and negative surprises and also the eye-widening was independent of the valence of the surprising target. In addition, in response to positive surprises, smiles were never observed right after the surprising stimuli and only occurred after some time passed (Experiments 3.1 and 3.2). So, also this more detailed expression-coding supports the view that initially, people respond to the unexpectedness of the outcome and only later, after sense-making, respond to the valence of the outcome. Moreover, a tentative conclusion is that frowning may be part of the initial response to a surprising stimulus[8].

If frowning regularly occurs in response to surprising events, the question remains how this should be interpreted. Corrugator activity might just reflect orientation (Van Dillen, Harris, Van Dijk, & Rotteveel, 2015; Yartz & Hawk, 2002), but it has also been related to mental effort (e.g., Van Boxtel & Jessurun, 1993) and negative affect (Topolinski, Likowski, Wyers, & Strack, 2009; Topolinski & Strack 2015). These latter connections would fit the notion that surprise reflects a negative state as a result of inconsistency and lack of meaning (Abelson et al., 1968; Gawronski & Strack, 2012; Kay et al., 2009; Miceli & Castelfranchi, 2015; Noordewier & Breugelmans, 2013; Proulx et al., 2012; Rutjens et al., 2013).

Finally, while we did not predict to find "typical" surprise expressions (based on Reisenzein et al., 2006; Reisenzein & Schützwohl, 2012), it is still intriguing that people think they show this

[8] Note that we do not find this in Experiment 3.1, where expressions were overall less intense than in Experiment 3.2. As such, it remains possible that the frowns were too subtle to detect without fEMG.

expression (see Reisenzein et al., 2006) and recognize the expression as surprise in others (e.g., Ekman et al., 1987). One possibility that is still untested is that this expression occurs when intending to *communicate* surprise. So, rather than a direct consequence of an internal state, people would raise their eye-brows, widen their eyes and drop their jaw to inform someone else that they are surprised. This would mean that a social context alone is not enough to induce the "typical" surprise expression (as indeed found in Reisenzein et al., 2006; Schützwohl & Reisenzein, 2012), but instead people should directly interact with each other. Future research could test this possibility.

Conclusion

When people are surprised, they initially respond to the unexpectedness of the event and later to the valence of the event. Two repetition-change studies supported this unfolding notion and showed that 1) after positive surprises, initial expressions are more negative than later expressions and 2) expressions to positive and negative surprises are initially similar and only start to differentiate depending on the valence of the event after some time. Finally, initial frowning was independent of the valence of the surprising target and this only later turned to smiles in the case of positive surprises. Taken together, these studies show that to study surprise, it is key to take its temporal dynamics into account and to distinguish surprise from the state that follows it.

PART II
CURIOSITY

CHAPTER 4

Curiosity and time: from not knowing to almost knowing

This chapter is based on: Noordewier, M. K., & Van Dijk, E. (2016). Curiosity and time: from not knowing to almost knowing. *Cognition and Emotion, in press*.

Acknowledgements: Thanks to Maryke Hofman, Carlo Konings, and Suzanne Kuiper for their help with collecting the data.

Curiosity and Time:
From Not Knowing to Almost Knowing

Curiosity is the desire to know (Kashdan & Silvia, 2009; Litman, 2005; Loewenstein, 1994; Silvia & Kashdan, 2009), which is triggered when people become aware of a gap in their knowledge and it instigates exploratory motivation aimed at closing this gap (e.g., Loewenstein, 1994; Silvia, 2012; Van Dijk & Zeelenberg, 2007). Curiosity thus reflects a state in which people lack information and are motivated to find out what it is.

Curiosity becomes more intense when the information-gap becomes smaller (Litman, Hutchins, & Russon, 2005; Van Dijk & Zeelenberg, 2007). So, people are more curious about the United States when they know 48 out of the 50 states than when they know only 14 (Loewenstein, 1994) and people get more curious about the content of a box when they also hear that the box contains something round (Van Dijk & Zeelenberg, 2007). The explanation for this increase in intensity is that with more (but not all) information available, the information-gap is perceived to be smaller and people focus more on what they do not know, which intensifies the desire to know (Loewenstein, 1994; see also Litman et al., 2005). Moreover, with more information available, people feel closer to finding out what the curiosity-inducing target is and closer to fulfilling their desire to know (Loewenstein, 1994).

Information-gap theory can be conceived as a cognitive theory that focuses on what information people miss and on what information people need to close the gap. We will build on this approach, but add a new element: Time. In doing so, we not only focus on *what* information is needed to close the gap, but also on *when* the gap will be closed; a feature we refer to as the "time to resolution." By varying the time to resolution, while keeping the amount of information constant, we tested how time affects how it feels to be curious. We predict that when people do not expect to close their information-gap soon, they are more likely to focus on the information-gap and the fact that they do not know something than when they can close their information-gap relatively quickly and almost know something. In this view, there are two sides to curiosity: the information-gap (not knowing) and the anticipation of the resolution (almost knowing). We predict that time affects how it feels to be curious, because it changes the relative impact of these two components: The longer the time to resolution, the weaker the anticipation of the resolution and the stronger the impact of the information-gap.

So, what does it mean to focus on the information-gap itself or its resolution? There is hardly any empirical work on how it feels to be curious, but there are different theoretical perspectives on both sides of curiosity. On the not knowing side, curiosity has been conceptualized as a state of knowledge deprivation (e.g., Loewenstein, 1994). In this view, curiosity is aversive because it frustrates people's desire to understand their environment and to have a sense of predictability, certainty, and structure (e.g., Berlyne, 1960, 1971; Gawronski & Strack, 2012; Kay, Whitson, Gaucher, & Galinsky, 2009; Litman, 2005; Noordewier & Breugelmans, 2013; Proulx, Inzlicht, & Harmon-Jones, 2012). In line with this, a recent imaging (fMRI) study showed that inducing curiosity activated brain areas related to conflict and arousal, while resolving it activated areas related to reward (Jepma, Verdonschot, Van Steenbergen, Rombouts, & Nieuwenhuis, 2012; for related work see Gruber, Gelman, & Ranganath, 2014; Han, Li, Warren, Feng, Litman, & Li, 2013; Kang et al., 2009; Maril, Simons, Weaver, & Schacter, 2005). In addition, knowledge-seeking studies show that people feel discomfort when they do not know something and even prefer knowing negative outcomes to staying ignorant (Kruger & Evans, 2009; Shani, Tykocinski, & Zeelenberg, 2008).

Contrary, and in our view more on the "almost knowing" side, curiosity has been related to positive emotions and to being interested in the unknown. In this view, curiosity is part of people's exploratory nature and it reflects the anticipation of discovering something new (e.g., Berlyne, 1960, 1971; Kashdan & Silvia, 2009; Litman, 2005; Noordewier & Van Dijk, 2015; Silvia, 2012; Silvia & Kashdan, 2009). This anticipation may be pleasurable in itself (e.g., Silvia, 2012) or it may be driven by the expected pleasure of closing the information-gap rather than the experience of curiosity itself (Loewenstein, 1994).

While it is difficult to unravel the exact nature of the desire to know, it seems plausible that a focus on not knowing (i.e., the information-gap) is more negative than a focus on almost knowing (i.e., anticipation of discovering something new; Kashdan & Silvia, 2009; Litman, 2005). That the subjective experience of curiosity might depend on whether people focus on missing information or the possibility of discovering something new can also be found in Litman's I/D model of curiosity that differentiates between curiosity as deprivation and curiosity as interest. Curiosity as deprivation refers to an uncomfortable wanting of information; curiosity as interest refers to a pleasurable anticipation of liking information (Litman 2005, 2008, 2010; for more information on wanting vs. liking systems and its neural processes, see Berridge 1999, 2003). Litman developed scales that reliably measure individual differences in deprivation- vs. interest-type curiosity (Litman, 2008; Litman & Jimerson, 2004; Litman & Spielberger, 2003). Studies show that dispositional deprivation-type curiosity is associated with uncertainty reduction, discomfort, tip of tongue experience, and low tolerance of ambiguity, whereas dispositional interest-type curiosity is associated with openness, anticipated fun of discovering something completely new, positive affect, and high tolerance of ambiguity (Collins, Litman, & Spielberger, 2004; Litman, 2008, 2010; Litman et al., 2005; Litman & Jimerson, 2004; Litman & Mussel, 2013).

When we combine this not knowing vs. almost knowing logic with our time-to-resolution perspective, this results in the prediction that curiosity is less pleasant when the resolution takes long as compared to short. Specifically, when the time to close the information-gap is long, the anticipation of the resolution is relatively weak and the aversiveness of not knowing something is more likely to become part of feeling curious. Contrary, when the time to close the information-gap is short, the anticipation of the resolution is stronger and the aversiveness of not knowing something is less likely to become part of feeling curious. Time thus may change whether people primarily *want* or *like* information (Berridge, 1999; Litman, 2005), as over time, people are predicted to move from feeling deprived to feeling interested. In line with this, the recent pleasure-interest model on aesthetic liking predicts a comparable effect of time (Graf & Landwehr, 2015), such that when processing goes more difficult or slower than expected it likely results in confusion, whereas when processing goes easier or faster than expected it likely results in interest.

So, clear predictions can be made regarding how the temporal proximity of the resolution affects how it *feels* to be curious. It is, however, less clear how time affects the *intensity* of curiosity. It could be that to the closer in time to the resolution, the stronger the curiosity—similar to increased motivation when people are closer in fulfilling their goal (i.e., goal-gradient hypothesis, cf. Hull, 1932; see e.g., Kivetz, Urminsky, & Zheng, 2006; see also Kruger & Evans, 2009; or approach-gradient principle of motivation, see Miller, 1959; Loewenstein, 1994). Yet, it seems also plausible that intensity will not be affected by temporal proximity, because the size of the information-gap stays the same. So, while the subjective experience of curiosity may differ, its intensity may not.

Finally, note that we do not argue that time-to-resolution affects curiosity in the same way as information-gaps. Rather, we propose that the time-to-resolution affects the impact of the information-gap. Like others (Litman et al., 2005; Loewenstein, 1994) we argue that when an information-gap is relatively small, people are more likely to focus on what they do *not know*, whereas when an information gap is relatively big, people are more likely to focus on what they *know*. In line with the reasoning outlined before, this focus on not knowing is associated with irritation, annoyance, and uncertainty, whereas bigger information gaps are more likely to be associated with enjoyment and the fun of discovery (Litman et al., 2005; Litman, 2008, 2010). This effect is modulated, however, by the time-to-resolution. The focus on not knowing is most strongly evoked in the case of a small information-gap with a long time-to-resolution. Based on this logic, the most aversive curiosity would thus be the result of a relatively small information-gap that takes a long time to resolve.

The Current Studies

To test our predictions, we compared the subjective experience and intensity of curiosity in a long vs. short time-to-resolution condition and measured how this develops over time. With a long compared to short time-to-resolution, not knowing something was predicted to influence curiosity more strongly, resulting in more discomfort and less positive affect. In addition, over time (i.e., going from a long to a short time-to-resolution, within participants), discomfort was predicted to decrease while positive affect increases, because people get closer to fulfilling their desire to know.

Specifically, Experiment 4.1 tested the effect of a long vs. short time-to-resolution on discomfort and positive affect. Experiment 4.2 extends this by also measuring the strength of the anticipation of the resolution and the extent to which people were bothered by not knowing. Moreover, we studied how the subjective experience of curiosity develops over time when participants go from a long to a short time-to-resolution. Finally, Experiment 4.3 aimed to replicate Experiment 4.2 and also tests potential moderating effects of individual differences in curiosity. We report all manipulations, all measures, and all data exclusions (if any). Based on recommendations by Simmons, Nelson, and Simonsohn (2011, 2013), sample sizes are at least 40 per cell. In our lab studies (Experiments 4.2 and 4.3) sample sizes are bigger, because we continued to collect data until the end of our lab time, which was one week.

Experiment 4.1

The first experiment aimed to provide a first test for the prediction that a long vs. short time-to-resolution results in more discomfort and less positive affect.

Method

Participants (N = 83) were recruited through MTurk (USA participants only, hit approval rate higher or equal to 96%) and randomly assigned to the 30- vs. 1-minute(s) to resolution condition. Participants were informed that we studied website content effects. While in reality the study took equally long for all participants, we told participants that depending on condition, the study would take either 35 or 5 minutes (instructions/measures adds some time to the 30 vs. 1 minute[s] to resolution) and that they would be paid according to the time they would need to complete the study. So, participants in the 30-minutes to resolution condition expected to receive more money than those in the 1-minute to resolution condition. We explained that for the study, they would visit a website containing a video. To make participants curious about the video, they read partial information about it (based on Van Dijk & Zeelenberg, 2007):

> Right now, we cannot say what the video is about. You will see this once you access the website. We can say, however, that the video will show something with different shades of brown. The video covers approximately half of the web page. The rest of the page is text.

Then, they continued to the next page where we manipulated the 30- vs. 1-minute(s) to the resolution:

> Before we give you the link, however, we would like to ask you to do some other unrelated tasks. These tasks take approximately 30 minutes [1 minute] and are generally experienced as interesting to do. After these 30 minutes [this minute], you can access the website with the video. So, there is half an hour [are only 60 seconds] between you and the website. After this half an hour [these 60 seconds] you can watch the video. The following pages will show a timer that counts down the 1800 [60 seconds] before you can access the website and watch the video. Please take a moment to think about the website and what the video might show. You will be able to continue shortly.

Next, we measured "To what extent are you eager to find out what is on the website?" and then "How do you feel right now?" on the item "curious", followed by a measure of *discomfort* (uncomfortable, uneasy, bothered; α = .82) and *positive affect* (good, happy, energetic; α = .90;

Elliot & Devine, 1994; all from 1 = *not at all* to 7 = *extremely*) and in this and the subsequent studies, we repeated the time-to-resolution information before asking the questions. Finally, for exploratory purposes, we asked participants to guess what the video would show. We reasoned that different feelings may results in different ideas about what the video could show (based on feelings-as-information, e.g., Schwarz, 1990). Then, the experiment ended and participants were debriefed.

Results

An independent samples *t*-test (Table 4.1) showed, as predicted, that participants in the 30- vs. 1-minute(s) to resolution condition experienced more discomfort, $t(70.460) = 3.01$, $p = .004$, $d = 0.67$. Conditions did not differ in eagerness, curiosity, or positive affect, ps > .32, ds = -0.08 to -0.21.

Table 4.1: Mean (and SD) eagerness, curiosity, positive affect, and discomfort as a function of Time (1 vs. 30 minute[s] to resolution; Experiment 4.1).

	1 min	30 min
eager	4.32^{a} (1.80)	4.18^{a} (1.92)
curious	4.57^{a} (1.90)	4.41^{a} (1.96)
positive affect	3.99^{a} (1.45)	3.66^{a} (1.64)
discomfort	2.13^{a} (1.20)	3.07^{b} (1.59)

Note: Means with different superscripts in rows differ at p = .004 in an independent sample t-test.

In this and the other studies reported, we coded the ideas about the content of the video. Two independent coders were instructed to code the valence of the answer (-2 = *negative*, -1 = *slightly negative*, 0 =

neutral, 1 = *slightly positive*, 2 = *positive*). The answers were very diverse and ranged from chocolate and poop to dirt, cats, and UPS drivers. We excluded seven participants who indicated to have no idea what to expect. When more than one answer was given, the valence of each answer was coded and an average was used in the analysis. The interraterreliability was good (r = .79) and codings were averaged. A *t*-test showed that conditions did not differ in valence of ideas (M_{30min} = 0.21, SD_{30min} = 1.14, vs. M_{1min} = 0.54, SD_{1min} = 0.85), $t(74)$ = -1.40, p = .17, d = -0.33. Participants in the 30-minutes to resolution condition did give marginally fewer answers (M = 1.06, SD = 0.16) than participants in the 1-minute to resolution condition (M = 1.22, SD = 0.52), $t(48.647)$ = -1.88, p = .07, d = -0.42.

Discussion

We found preliminary support for our prediction that people experience more discomfort when they expect it takes relatively long to close their information-gap than when they expect this can be done quickly. It did not result in differences in curiosity, positive affect, or valence of ideas about the content of the video.

One might argue that the discomfort in the 30-minutes to resolution condition is due to participants expecting to do unrelated tasks which they may not feel like doing, even though participants in this condition expected to receive more money than the 1-minute to resolution condition and we stressed that the tasks were generally experienced as interesting. To address this possibility, Experiment 4.2 tests the same predictions in a lab session that was equally long for all participants: Participants were recruited to participate in different studies that together took one hour. They were informed about the different studies through an informed consent, so every participant knew a) what type of studies were coming, and b) that the session would take an hour. As such, any effect of time on discomfort cannot be explained by different ideas about tasks ahead or the time it would take to finish the session.

Experiment 4.2

In Experiment 4.2, we again tested the effect of time on discomfort and positive affect. In addition, we tested whether a long vs. short time-to-resolution weakens the anticipation of the outcome while increasing annoyance with lack of information. Moreover, besides testing the differences between the long vs. short time-to-resolution conditions, we also investigated how the subjective experience developed over time *within* the long time-to-resolution condition, by measuring the dependent measures in the long time-to-resolution situation (time 1) as well as when time passed and they were as close to the resolution as the short time-to-resolution participants (time 2). Finally, we now also actually showed participants a video and asked them to evaluate it to see whether a long vs. short time-to-resolution affects its appreciation.

Method

Participants (N = 141; 108 females, 33 males; M_{age} = 20.01 years, SD_{age} 1.95) visited the Leiden University lab and they were randomly assigned the 30- vs. 1-minute(s) to resolution condition. Participants were told that we investigated factors predicting the (un)pleasantness of online videos and that they would evaluate a video. We said that (translated from the original Dutch):

> At this point, we cannot say what the video is about. You will see this once you access the page. We can say that the video takes approximately a minute and it shows something with different shades of brown.

Next, they were asked to think about what the video might show for a couple of seconds. Then we manipulated time. Similar to Experiment 4.1, before watching the video, they were requested do some other unrelated task, which would take either approximately 30 or 1 minute(s). To strengthen the manipulation, we additionally said:

> So there is half an hour [only 60 seconds] between you and the video. After this half an hour [60 seconds] you can watch the video. Thus, it takes some time before the video is shown. [Thus, the video will be shown shortly.]

Then, the study continued to the dependent variables. With the same items as in Experiment 4.1 (translated to Dutch), we measured curiosity, discomfort (α = .70), and positive affect (α = .85). Next, we measured lack of information annoyance with, "I think it is bothersome that I do not know what the video is about", and "I think it is annoying that I lack information about the content of the video" (α = .87). Finally, we checked the temporal proximity of the resolution with, "I am about to discover what the video is about" and "The content of the video is almost tangible" (α = .81; all from 1 = *not at all*, 7 = *extremely*). Finally, we asked participants to guess what the video would show (open question).

For the participants in the 1-minute to resolution condition, these were all the dependent measures and they could continue to watch the video (showing Siberian Grizzly bears) and evaluate it on the items "interesting" and "boring" (reversed scored; α = .89). For participants in the 30-minutes to resolution condition, this was the time 1 measure. All measures were asked again after they did another experiment testing possible gender biases in hiring decisions. After this unrelated study, they returned to the current study and before watching the video, they answered the same items as before (time 2), measuring curiosity, discomfort (α = .89), positive affect (α = .80), lack of information annoyance (α = .93), and outcome anticipation (α = .61). Then, they watched the video and evaluated it on the interesting/boring scales (α = .89). At the end of the session, all participants were thanked and debriefed.

Results

We compared the 30- vs. 1-minute(s) to resolution condition with independent samples *t*-tests (Table 4.2a). Replicating Experiment 4.1, we found that conditions did not differ in reported curiosity, $t(139) = -1.47$, $p = .14$, $d = -0.24$. As predicted, participants in the 30- vs. 1-minute(s) to resolution condition experienced more discomfort, $t(139) = 3.02$, $p = .003$, $d = 0.50$, and less positive affect, $t(139) = -2.87$, $p = .005$, $d = -0.48$. In addition, in the 30- vs. 1-minute(s) to resolution condition, they had weaker outcome anticipation, $t(139) = -7.58$, $p < .001$, $d = -1.28$. No differences were found on lack of information annoyance, $t(139) = 0.97$, $p = .34$, $d = 0.16$. Finally, we compared video evaluations (note that this is measured at time 2 in the 30-minutes to resolution condition). Participants in the 30-minutes to resolution condition evaluated the video more negatively than participants in the 1-minute to resolution condition, $t(139) = -3.13$, $p = .002$, $d = -0.53$.

Table 4.2a: Mean (and SD) curiosity, positive affect, discomfort, lack of information annoyance, outcome anticipation, and video evaluation as a function of Time (1 vs. 30 minute[s] to resolution) and within the 30-minutes to resolution condition (time 1 vs. time 2; Experiment 4.2).

	1 min	30 min time 1	30 min time 2
curiosity	5.25^{a}	4.93^{a}	5.13^{a}
	(1.13)	(1.48)	(1.51)
positive affect	4.69^{a}	4.12^{b}	4.66^{a}
	(0.97)	(1.36)	(1.07)
discomfort	2.33^{a}	2.92^{b}	2.60^{a}
	(1.17)	(1.15)	(1.39)
lack of information annoyance	2.99^{ab}	3.24^{a}	2.80^{b}
	(1.52)	(1.55)	(1.60)
outcome anticipation	5.07^{a}	3.53^{b}	5.12^{a}
	(1.14)	(1.27)	(1.23)
video evaluation	4.48^{a}		3.65^{b}
	(1.63)		(1.52)

Note: Means with different superscripts in rows differ at $p < .01$ in an independent sample t-test comparing the 1-minute vs. 30-minutes condition or a paired-sample t-test comparing 30-minutes to resolution at time 1 vs. time-2.

Next, *within* the 30-minutes to resolution condition we compared t1 and t2 with paired-sample *t*-tests (Table 4.2a). We found that after 30 minutes, participants did not become less or more curious, $t(69)$ = -

1.14, $p = .26$, $d = -0.13$ (for information on *d*-values in repeated measures, see Dunlop, Cortina, Vaslow, & Burke, 1996), but they did experience more positive affect, $t(69) = -4.76$, $p < .001$, $d = -0.44$, less discomfort, $t(69) = 2.93$, $p = .005$, $d = 0.25$, less lack of information annoyance, $t(69) = 2.80$, $p = .007$, $d = 0.28$, and stronger outcome anticipation, $t(69) = -9.14$, $p < .001$, $d = -1.27$.

Then, if our prediction that time to the resolution affects the subjective experience of curiosity is correct, there should be no difference between t2 in the 30-minutes to resolution condition and the 1-minute to resolution condition, as the resolution is now equally close. *T*-tests indeed showed no differences on any of the dependent measures, all *t*s(139) between -0.74 and 1.24, *p*s > .21.

Finally, we coded the valence of the ideas about the content of the video in the same way as in Experiment 4.1. The interraterreliability was sufficient ($r = .77$). Conditions did not differ on valence of ideas ($M_{30min} = 0.32$, $SD_{30min} = 0.91$ vs. $M_{1min} = 0.47$, $SD_{1min} = 0.79$), $t(137) = -1.07$, $p = .29$, $d = -0.18$, or the number of answers given ($M_{30min} = 2.27$, $SD_{30min} = 1.42$ vs. $M_{1min} = 2.22$, $SD_{1min} = 1.27$), $t(137) = 0.24$, $p = .81$, $d = 0.04$.

Discussion

A long vs. short time-to-resolution resulted in more discomfort, less positive affect, and weaker outcome anticipation. Also, while it did not change the valence of the ideas about the content of video, a long vs. short time-to-resolution did lower video evaluation. Finally, over time, participants in the long time-to-resolution condition experienced less discomfort, more positive affect, less lack of information annoyance and a stronger anticipation of the resolution.

We assume that the effects of time are due to the relative impact of not knowing vs. almost knowing and we reasoned that the current set-up ruled out potential effects of expectancies about the task or time to finish. Yet, even though participants in the 1-minute to resolution condition did the same tasks for the same amount of time as participants in the 30-minutes to resolution condition, perhaps the duration of the lab session was more on top of participants' mind in the 30- than the 1-minute(s) to resolution condition. To rule out the possibility that this could explain the discomfort findings, we repeated Experiment 4.2 with an extra condition emphasizing the duration of the lab session (Experiment 4.2b; N = 194; 140 females, 54 males; M_{age} = 21.88 years, SD_{age} = 4.91). Specifically, we compared the 30-minutes (like Experiment 1, only time 1) vs. 1-minute to resolution condition to a 1-minute to resolution condition where we additionally emphasized the remaining time in the lab session. After the 1-minute instructions, participants in this condition read: "After viewing the video, the other studies you read about in the informed consent will follow. The studies in the rest of the session take 30 minutes". We repeated that "the rest of the sessions takes half an hour" before the dependent measures.

Results again showed that the 30- vs. 1-minute(s) to resolution condition resulted in more discomfort, less positive affect, weaker outcome anticipation, and marginally more lack of information annoyance, while the 1-minute to resolution condition did not differ from the 1-minute to resolution including session-time reminder condition (see Table 4.2b for means and post hoc LSD tests). This further corroborates the notion that time to the resolution affects the subjective experience of curiosity.

Table 4.2b: Mean (and SD) curiosity, positive affect, discomfort, lack of information annoyance, and outcome anticipation as a function of Time (1 minute vs. 1 minute + session time vs. 30 minutes to resolution; Experiment 4.2b).

	1 min	1 min + session time	30 min
curiosity	5.12[a]	5.32[a]	5.03[a]
	(1.18)	(1.27)	(1.27)
positive affect	4.77[a]	4.78[a]	4.39[b]
	(0.97)	(1.10)	(1.02)
discomfort	2.30[a]	2.36[a]	2.76[b]
	(0.99)	(1.19)	(1.22)
lack of information annoyance	2.90[a]	2.88[a]	3.39[b*]
	(1.63)	(1.58)	(1.72)
anticipation of outcome	4.72[a]	4.89[a]	3.49[b]
	(1.11)	(1.19)	(1.38)

Note: Means with different superscripts in rows differ at $p < .05$ and with * differ at $p <= .10$, LSD post hoc tests.

Experiment 4.3

In Experiment 4.3, we aimed to replicate Experiment 4.2 and for exploratory purposes, we tested potential effects of individual differences in curiosity, measured with the Curiosity Exploration Inventory (CEI-II; Kashdan et al., 2009). CEI-II measures the extent to which people are motivated to look for new knowledge and experiences (stretching subscale) and embrace the uncertainty and unpredictability of everyday situations (embracing subscale). We reasoned that low curious people may be more bothered by not knowing than high curious people, who might not experience unpleasantness at all. We did not have specific predictions for the different subscales.

Method

A total of 115 participants (95 females, 20 males; M_{age} = 22.05 years, SD_{age} = 4.52) visited the Leiden University lab. First, the CEI-II was administered. To avoid that participants would associate the pre-measure with the main study, they then did an unrelated study about gender stereotypes in advertising. After this, they were randomly assigned to one of two time conditions: 30- vs. 1-minute(s) to resolution—similar to Experiment 4.2, except that the study between the t1-t2 measures within the 30-minutes to resolution condition was now on value conflicts. Also, we checked whether participants had participated in the previous study: 15 participants who indicated they did were excluded from the analyses. We analyzed the data of the remaining 100 participants (M_{age} = 22.04 years, SD_{age} = 4.78; 83 females).

Results

We compared curiosity, discomfort, positive affect, lack of information annoyance, outcome anticipation, and video evaluation in the 30- vs. 1-minute(s) to resolution condition with independent samples *t*-tests (Table 4.3). Replicating Experiments 4.1 and 4.2, we found no differences in reported curiosity, $t(98) = 0.79$, $p = .43$, $d = 0.16$, while participants in the 30- vs. 1-minute(s) to resolution condition experienced more discomfort, $t(98) = 1.96$, $p = .05$, $d = 0.39$, less positive affect, $t(98) = -2.45$, $p = .02$, $d = -0.50$, more lack of information annoyance, $t(98) = 3.52$, $p = .001$, $d = 0.70$, and weaker outcome anticipation, $t(98) = -2.43$, $p = .02$, $d = -0.49$. Contrary to

Experiment 4.2, no video evaluation differences were found, $t(98) = -1.18$, $p = .24$, $d = -0.24$.

Next, we compared t1 and t2 within the 30-minutes to resolution condition with paired-sample *t*-tests (Table 4.3). Replicating Experiment 4.2, we found no differences on reported curiosity, $t(49) = 0.91$, $p = .37$, $d = 0.12$, but at t2 participants did experience less discomfort, $t(49) = 2.34$, $p = .02$, $d = 0.32$, less lack of information annoyance, $t(49) = 2.42$, $p = .02$, $d = 0.25$, and stronger outcome anticipation, $t(49) = -5.09$, $p < .001$, $d = -0.81$. No positive affect differences were found, $t(49) = -1.53$, $p < .13$, $d = -0.19$.

Table 4.3: Mean (and SD) curiosity, positive affect, discomfort, lack of information annoyance, and outcome anticipation as a function of Time (1 vs. 30 minute[s] to resolution) within the 30 minutes to resolution condition (time 1 vs. time 2; Experiment 4.3).

	1 min	30 min time 1	30 min time 2
curiosity	5.34[a]	5.52[a]	5.38[a]
	(1.17)	(1.11)	(1.28)
positive affect	4.79[a]	4.31[b]	4.51[ab]
	(0.89)	(1.03)	(1.03)
discomfort	2.11[a]	2.56[b]	2.16[a]
	(1.03)	(1.27)	(1.26)
lack of information annoyance	2.61[ac]	3.68[b]	3.25[c]
	(1.41)	(1.62)	(1.81)
anticipation of outcome	4.36[a]	3.59[b]	4.85[a]
	(1.62)	(1.55)	(1.55)
video evaluation	4.41[a]		4.04[a]
	(1.52)		(1.62)

Note: Means with different superscripts in rows differ at $p <= .05$ in an independent sample t-test comparing the 1-minute vs. 30-minutes to resolution condition and at $p < .03$ in a paired-sample t-test comparing 30-minutes to resolution at time 1 vs. time 2.

Then we again compared 30-minutes to resolution condition at t2 with the 1-minute to resolution condition. As before, we found no differences, *t*s(98) between -1.46 and 1.55, *p*s > .12, except on lack of information annoyance, $t(98) = -1.97$, $p = .05$. So, participants in the 30-minutes to resolution condition at t2, being equally close to the resolution as participants in the 1-minute to resolution condition, responded similar to those in 1-minute to resolution condition.

Next, we coded the valence of the ideas about the content of the video in the same way as in Experiments 4.1 and 4.2. The interraterreliability was sufficient ($r = .74$). Conditions did not differ on valence of ideas ($M_{30min} = -0.03$, $SD_{30min} = 0.87$ vs. $M_{1min} = 0.19$, $SD_{1min} = 0.92$), $t(110) = -1.32$, $p = .19$, $d = -0.25$, or the number of answers given ($M_{30min} = 1.75$, $SD_{30min} = 1.21$ vs. $M_{1min} = 1.76$, $SD_{1min} = 0.95$), $t(110) = -0.09$, $p = .93$, $d = -0.01$.

Finally, we checked for effects of the Curiosity and Exploration Inventory. After computing CEI-stretching ($\alpha = .71$) and CEI-embracing ($\alpha = .73$) subscales (Kashdan et al., 2009), we ran ANCOVA's with each standardized subscale, Time and their interaction on all dependent measures. The Time/CEI-stretching ANCOVA showed a marginal CEI-stretching main effect on anticipation, $F(1, 96) = 3.18$, $p = .08$. The effects of Time remained the same as before (all *p*s < .05, except discomfort, $p = .08$, curiosity *ns*). No other effects were found (*p*s > .12). The Time/CEI-embracing ANCOVA showed a CEI-embracing main effect on anticipation, $F(1, 96) = 4.92$, $p = .03$, and Time x Embracing interaction on lack of information annoyance, $F(1,96) = 4.84$, $p = .03$. The effects of Time remained the same as before (*p*s <= .06, curiosity *ns*). No other differences were found (*p*s > .10).

To interpret the Time x Embracing interaction, we ran a regression with low and high embracing (standard deviation below/above the mean, following Aiken and West, 1991) on lack of information annoyance. This showed the Time x Embracing interaction, B = 0.69, $t(96) = 2.23$, $p = .03$, and a low/high embracing main effect, B = -0.50, $t(96) = -2.32$, $p = .02$. For high embracers, there was no difference between the 30- and 1-minute(s) condition, B = -0.32, $t(96) = -.73$, $p = .47$ ($M_{1min} = 2.72$ vs. $M_{30min} = 3.08$), whereas for low embracers it remained, B = -1.69, $t(96) = -3.88$, $p < .001$ ($M_{1min} = 2.38$ vs. $M_{30min} = 4.07$). So, low embracers were more bothered by lack of information in the 30- vs. 1-minute(s) to resolution condition, but there was no difference for high embracers.[9]

Discussion

Experiment 4.3 replicated the main results of Experiment 4.2 by showing that a long vs. short time-to-resolution resulted in more discomfort, less positive affect, more lack of information annoyance, and weaker outcome anticipation. The time-to-resolution did not affect the valence of the ideas about the content of the video and in this

[9] We also included Consideration for Future Consequences (CFC-14; Joireman, Shaffer, Balliet, & Strathman, 2012). People with a strong future-focus may realize that the information-gap will be closed, lowering the effect of time. Analyzing both future/immediate-focus subscales, only a Time x Future-Focus interaction on positive affect was found, B = 0.42, $t(96) = 2.11$, $p = .04$: The long vs. short time-to-resolution condition did not differ for high future-focused people ($M = 4.58$ vs. $M = 4.51$); low future-focus people were more positive in the short vs. long time-to-resolution condition ($M = 4.92$ vs. $M = 4.02$). No other effects were found. For ease of presentation, we excluded this from the method/results.

study, it also did not affect video evaluation. In addition, when participants in the long time-to-resolution condition came closer to the resolution, they responded similar to those in the short time-to-resolution condition. Finally, for people who strongly embrace the uncertainty and unpredictability of everyday situations, time did not affect lack of information annoyance. So, even though we did not find this effect on discomfort, it is plausible that for these people, the not knowing component of curiosity is not as aversive as for people who rather have certainty and predictability. It should be noted, however, that a general willingness to embrace uncertainty is not necessarily the opposite of discomfort as the result of such uncertainty. Future research could incorporate scales that directly measure the extent to which people feel uncertain when lacking information, such as Litmans's (2008) scale measuring deprivation- and interest-type curiosity (see also Litman & Jimerson, 2004; Litman & Spielberger, 2003; for correlations between I/D curiosity and the first version of the CEI, see Litman & Mussel, 2003).

General Discussion

This research focused on how it feels to be curious. We reasoned that there are two sides to curiosity: An information-gap, which is an unpleasant deprived state of not knowing something (e.g., Jepma et al., 2012; Kruger & Evans, 2009; Loewenstein, 1994; Shani et al., 2008), and an anticipation of resolving this lack of information, which is an exciting state of almost knowing something (e.g., Silvia & Kashdan, 2009). We showed that the time to the resolution of curiosity affects the relative impact of these two components: When people did not expect to close their information-gap soon (long time-to-resolution), the anticipation of the resolution was weaker and not knowing something affected the subjective experience of curiosity more strongly than when they expected to close their information-gap quickly (short time-to-resolution). As such, people experienced less positive affect, more discomfort, and they were more bothered by the lack of information in a long vs. a short time-to-resolution. In addition, when time in the long time-to-resolution passed, people more strongly anticipated the resolution, they experienced more positive affect, less discomfort, and they were less bothered by the lack of information.

While the results generally confirm our predictions, there are some elements that warrant further discussion. First, it should be noted that the reported discomfort and lack of information annoyance were relatively low (i.e., below the midpoint of the scale). This may (at least partly) be driven by the fact that we tested our predictions in the context of online videos, which are probably perceived as interesting and a source of entertainment. When the curiosity-inducing target is less positive or its valence is unclear, it seems plausible that the not knowing discomfort levels are higher.

Also, while temporal proximity of the resolution resulted in different feelings, it did not affect the intensity of curiosity in any of the studies. The most straightforward explanation for this finding is that the size of the information-gap affects intensity (Litman et al., 2005; Loewenstein, 1994; Van Dijk & Zeelenberg, 2007), but since this was held constant we found similar intensity levels. The fact that the time-to-resolution did not affect intensity may be taken to imply that not knowing and almost knowing are equally related to curiosity, supporting the view that there are indeed two sides to curiosity that affect the experience of curiosity differently depending on the temporal proximity of the resolution (for more on the importance of temporal dynamics in sense-making, see Noordewier, Topolinski, & Van Dijk, 2015).[10]

Finally, while we did not find consistent effects on our exploratory measures (i.e., video evaluation, ideas of video content, individual differences in curiosity), they might still provide a base for future research. First, it could be more systematically tested whether a long vs. a short time-to-resolution lowers the evaluation of the target, as found in Experiment 4.2 but not in Experiment 4.3. This finding may, for instance, be more robust when people experience higher levels of curiosity. In addition, we did not find any evidence for the notion that time (and thus feelings) affects the valence of ideas of the content of the target. Yet, it remains possible that with more intense discomfort levels, people also expect more negative targets. All in all, the current studies constitute one of the first systematic empirical assessments of the subjective experience of curiosity and future research could try to

[10] Participants in Kruger and Evans (2009; Study 3) more often chose ignorance about a negative outcome when they expected to gain this knowledge after 10 months compared to immediately. This effect was mediated by the extent to which participants thought the information would satisfy their curiosity. While satisfying curiosity is different from feeling curious, it remains possible that curiosity intensity decreases when time-to-resolution is extremely long. Then, the outcome may seem relatively unreachable, lowering the motivation resolve it.

replicate and extend the findings in a different, preferably a more intense, context.

Next, it should be noted that the task in our studies is rather perceptual and it could be argued that our findings fit a perceptual curiosity framework (Collins et al., 2004; Litman & Spielberger, 2003). Perceptual curiosity is the result of complex, new, or ambiguous sensory stimuli and it motivates visual, auditory, or tactile inspection (Berlyne, 1954; Collins et al., 2004). This is different from epistemic curiosity, which is the result of by conceptual puzzles or complex ideas and motivates asking questions or testing hypothesis to gain knowledge (Berlyne, 1954; Litman & Spielberger, 2003). We do not expect that the time to the resolution of curiosity would work markedly different for perceptual or epistemic situations, as long as people lack information about something specific.

There is, however, also *diversive* curiosity (Day, 1971), which refers to people looking for new and interesting things for the sake of stimulation, rather than for any specific outcome. With diversive curiosity, it is less likely that people focus on something they do not know and time is predicted to affect people differently. That is, diversive curiosity relates to exploratory behavior in situations that lack clear temporal or informational end-points, like wandering around in an unknown town or exploring nature without a particular destination. In situations like this, there is an information-gap in the sense that the situation is unknown and people are likely to experience curiosity regarding what they might discover. Yet, there is not necessarily one piece of information that could close this information-gap (i.e., the information-gap itself is unknown), nor does spending a lot of time seem unpleasant. There are thus numerous possibilities for gaining knowledge and any information could fulfil this type of desire to know. This potential may make these situations enjoyable. In other words, this type of not knowing may not be that aversive but is likely to be experienced as positive (as the time spent and as also the items in the Curiosity and Exploration Inventory suggest; Kashdan et al., 2009). It should be noted, however, that people may not want to approach the unknown without the feeling that they are able to cope with it. For instance, people only experience interest when they also have coping potential (Silvia, 2005) and complex novelty is more interesting when people feel they can deal with it (Noordewier & Van Dijk, 2015). So, it seems that people only tolerate or enjoy the uncertainty of the unknown when they appraise the situation as manageable.

Finally, it could be argued that a long time-to-resolution resembles delay of gratification of resolving the information-gap (Metcalfe & Mischel, 1999; Mischel, 1974). This introduces possible connections between the time-to-the-resolution of curiosity and self-control. In typical delay of gratification settings, the gratifying outcome is present and people have to engage in self-control to inhibit their impulse to go for it (e.g., a marshmallow; Mischel, Ebbesen, & Zeiss, 1972). For curiosity, this could match situations where the resolving outcome is already present and people have self-imposed time-to-resolution—for instance, when having to wait to open a gift or resisting the temptation to go to the last page of a book to find out the end of a story. In many curiosity situations, however, the resolving outcome is not yet present and the time to the resolution involves information-search or simply awaiting what will follow. Especially when people feel deprived of information (i.e., in a long time-to-resolution situation), self-control could benefit persistence or patience. In line with this, people who are high in dispositional deprivation-type curiosity also report higher impulse control (Litman & Mussel, 2013; Piotrowski, Litman, & Valkenburg, 2014) as well as increased scores on other self-regulatory dimensions such as emotional restraint and thoughtful evaluation (Lauriola, Litman, Mussel, De Santis, Crowson, & Hoffmann, 2015).

Conclusion

Time is a key factor in the experience of curiosity. It is less pleasant when people do not expect to close their information-gap soon than when they can close their information-gap quickly. Given that there is hardly any empirical work on how it feels to be curious, the current studies contribute to the different theoretical accounts on curiosity and also offer a starting point to integrate seemingly opposing views. Knowledge deprivation (e.g., Loewenstein, 1994) and interest in the unknown (e.g., Kashdan & Silvia, 2009) are both part of curiosity as with time, curiosity goes from not knowing to almost knowing.

CHAPTER 5

Interest in complex novelty

This chapter is based on: Noordewier, M. K., & Van Dijk, E. (2016). Interest in complex novelty. *Manuscript submitted for publication*.

Acknowledgements: Thanks to Laura Broeks and Jacqueline Rutgers for their help with collecting the data of Experiment 5.1. Thanks to Fréderique Arntz and Linda Muijs for their help with coding the stories of Experiment 5.3. Thanks to Peter de Heus for his advice on statistics.

Interest in Complex Novelty

In the future, people may control devices with their brainwaves, influence the weather with cloud making machines, and clean their house using robotic cleaning flies. This is just a snapshot of the numerous new products and technologies that are currently being developed[11] and that may find their way into people's daily lives. Innovation may provide people with many new and useful things and people most likely first hear about it via news coverage or through websites that focus specifically on technological innovation. Journalists, bloggers, or developers communicate about what is new and the widespread attention for, for instance, products introduced at the yearly Consumer Electronics Show (CES; see cesweb.org) suggests that the assumption is that many people are interested in new and innovative things.

Interestingly, though, many new products fail (the estimated failure rate ranges from 40% in Castellion and Markham, 2012, to 75% in Schneider and Hall, 2011; see also Cierpicki, Wright, and Sharp, 2000)[12]. So, even though new products and technologies may be exciting, useful, and often enthusiastically communicated about, success is sometimes hindered. The question is how to introduce novel products to increase

[11] For brainwaves tattoo see: ideaconnection.com/new-inventions/temporary-tattoos-could-make-telekinesis-possible-06794.html; for cloud making machine see: ideaconnection.com/new-inventions/cloud-making-machine-could-help-offset-climate-change-06674.html; for robotic cleaning flies see: electroluxdesignlab.com/en/submission/mab/links

[12] Failure rates differ somewhat between industries (e.g., in 2004 there were more failures in consumer goods/services [45%] than health care [36%], cf. Castellion & Markham, 2012). See also Best Practices study by the Product Development & Management Association's (PDMA).

the chance that people will become interested in it. One issue that may play a role is that novelty can be challenging because it may come with unfamiliarity and a difficulty understanding it (e.g., Mukherjee & Hoyer, 2000; Rindova & Petkova, 2007; see also Oreg, 2003; Oreg & Goldenberg, 2015). This does not concern "simple" novelty like new flavors or modernized package design, but is rather an issue of complex novelty like technological change. Complex novelty is the combination of atypicality/unfamiliarity (novelty) and difficulty of understanding this at first sight (complexity: see also Berlyne, 1960, 1971; Silvia, 2005). People might resist complex novelty because they experience uncertainty regarding its purpose and meaning (see also Antioco & Kleijnen, 2010; Carbon & Schoormans, 2012; Castaño, Sujan, Kacker, & Sujan, 2008; Kleijnen, Lee, & Wetzels, 2009; Hoeffler, 2003; Oreg & Goldenberg, 2015). So, to become interested in complex novelty, it is key that people have a sense that they can cope with it. This has concrete implications for how complex novelty should be introduced to people.

Complex Novelty

Complex novelty can be exciting in terms of promising possibilities, but people might also feel that they do not exactly grasp what it is or what it is for (see also Berlyne, 1971; Hoeffler, 2003; Mukherjee & Hoyer, 2000). For example, robotic cleaning flies may offer the prospect of saving a lot of time cleaning, but at the same time it is not really clear how these little robots find dirt or what it means that they fly around in one's house. This lack of understanding might confront people with an information-gap, which can make them curious and motivated to find out more about it (e.g., Loewenstein, 1994; Noordewier & Van Dijk, 2015; Silvia & Kashdan, 2009). At the same time, it can challenge people's preference to understand their environment and their need for certainty, predictability, and structure (e.g., Abelson et al., 1968; Gawronski & Strack, 2012; Kay, Whitson, Gaucher, & Galinsky, 2009; Noordewier & Breugelmans, 2013; Proulx, Inzlicht, & Harmon-Jones, 2012). Not understanding complex novelty may actually lower interest rather than promote interest, as people may find it difficult to deal with.

Research on the appraisal structure of interest also points to the importance of feeling able to deal with complex novelty. In particular, it has been argued that feeling interested is driven by a combination of a novelty-complexity appraisal and a coping potential appraisal (Silvia 2005; see also Kashdan & Silvia, 2009; Silvia, 2008). The novelty-complexity appraisal refers to the evaluation of an event as new, unexpected, complex, hard to process, surprising, mysterious, or obscure. The coping potential appraisal is the estimation of having the skills, knowledge, and resources to deal with an event (cf. Silvia, 2005). Complex novelty obviously meets the first appraisal, but the question is whether people experience sufficient levels of coping potential to experience interest, as the complexity component may actually interfere with this. So, the more complex and novel a product is, the less likely it becomes that people experience coping potential. This is also in line with Berlyne's notion (e.g., Berlyne, 1960, 1971) that people want to avoid things that become too novel because they are too arousing (see also Noseworthy, Di Muro, & Murray, 2014) and findings that show that “most advanced, yet acceptable” (MAYA) works best in industrial design (cf. Blijlevens, Carbon, Mugge, & Schoormans, 2012; Hekkert, Snelders, & Van Wieringen, 2003).

Coping with Complex Novelty

Importantly, this logic also provides clear directions on how to increase interest in complex novelty. By increasing people’s coping potential with complex novelty, interest in it should increase as well. Supporting this, interest in art appears to be positively related to understanding the meaning of the artwork (e.g., provided via titles of abstract art or extra information about a poem; Millis, 2001; Silvia, 2005), given that people have sufficient time to process the meaning of the information (Leder, Carbon, & Ripsas, 2006). Also, research has shown that interest in an unclear task was highest when people experience moderate levels of self-efficacy, whereas low and high self-efficacy resulted in lower interest because the task was respectively too difficult or too easy (Silvia, 2003). In addition, in a theoretical analysis of technological change and product design, Rindova and Petkova (2007) argued that people might be better able to cope with novel technologies when they are presented in a familiar product design, because the familiarity makes it easier to comprehend.[13] Finally, Carbon and Leder (2005) showed that innovative product design becomes more attractive when people are repeatedly exposed to it (see also Carbon &

[13] A nice illustration of this logic is Horsey Horseless (cf. Rindova & Petkova, 2007), a car that was presumably invented in 1899 with a head of a horse (i.e., more familiar as means for transportation) attached to the front to make people feel more at ease with the strange new vehicle. For an image, see content.time.com/time/specials/2007/article/0,28804,1658545_1657686,00.html and to read about the idea to make the horse head hollow to be able to put fuel in it.

Leder, 2007), presumably because the extra elaboration increases their understanding of the product. Taken together, these insights suggest that when introducing complex novelty, interest might be increased by making it easier to understand rather than only highlighting the innovative elements.

Yet, in addition to increasing *actual* coping potential (i.e., product-specific understanding), it is also plausible that a more general subjective feeling of coping potential increases interest in complex novelty. In this view, people are predicted to become more interested in complex novelty when they *perceive* they can deal with complex novelty, such that they can tolerate or even enjoy the unfamiliarity and difficult to understand component of complex novelty. Perceived coping potential thus refers to general psychological state in which people evaluate complex novelty, which is independent of features of the complex novelty itself.

Indirect evidence indeed points to such a relation between perceived coping potential and people's preference for predictability and familiarity. For instance, when people experience high as opposed to low personal control, they are more likely to accept disorder and randomness (e.g., Rutjens, Van Harreveld, Van der Pligt, Kreemers, & Noordewier, 2013; see also Kay et al., 2009) and thus possibly also novelty. In addition, people who feel certain are more likely to go for novel products whereas people who feel uncertain are more likely to prefer familiarity (Oishi et al., 2012; see also Van Horen & Pieters, 2013). Finally, people who focus on fascination or growth appreciate novelty more than people who focus on danger or maintaining or attaining security (Carbon, Faerber, Gerger, Forster, & Leder, 2013; promotion vs. prevention focus, Gillebaart, Förster, & Rotteveel, 2012).

Although rather diverse and not always focusing on *complex* novelty, these findings suggest that contextual factors related to coping potential predict preferences for novel or disorderly targets. Translating this to interest in complex novelty, this suggests that when people are in a state of high coping potential, they feel they can deal with the unfamiliarity and difficulty component of complex novelty, whereas when they are in a state of low coping potential, this same unfamiliarity and difficulty component can be experienced as challenging or even stressful (e.g., Oishi et al., 2012). As such, people are predicted to be more interested in complex novelty when they feel they have high vs. low coping potential. When introducing complex novelty, it is therefore important to do this in settings where people feel they can cope.

Importantly, this may provide innovators with alternative means to increase interest in complex novelty. Rather than concentrating only on increasing product-specific understanding (actual coping potential) they may benefit from increasing the idea that people can cope (perceived coping potential). Moreover, this logic suggests that coping potential can affect interest without changing novelty-complexity evaluations. This may be of importance to innovators, who might worry that increasing coping potential lowers the perceived innovativeness of their products. In addition, this implies that the two appraisals underlying interest (novelty-complexity and coping potential; Silvia, 2005) can independently produce interest.

In sum, it seems that people need to have a sense that they can understand complex novelty to become interested in it. This can either be through *actual* coping potential (i.e., product-specific understanding) or through *perceived* coping potential (i.e., feeling able to deal with difficulty understanding). We predict that people who experience relatively high actual or perceived coping potential are more interested in complex novelty than people who experience relatively low actual or perceived coping potential. To test this hypothesis, we measure interest in complex new products (Experiments 5.1 and 5.2) and recent inventions (Experiment 5.3), after increasing actual coping potential by communicating similarity with familiar products (Experiments 5.1 and 5.2) or after increasing perceived coping potential in an autobiographical recall task (Experiment 5.3). In all studies, we included novelty and complexity measures, to test the (in)dependence of the novelty-complexity and coping potential appraisals.

Pretest

To select complex novel stimuli for Experiments 5.1 and 5.2, we conducted a pretest. We selected 12 complex novel products based on an internet search. An Amazon's Mechanical Turk (MTurk) sample (*N* = 30; US participants only and at least 96% of previous studies completed [i.e., hit rate]; age/gender information unavailable) viewed pictures of the products in random order, including the product name: robot vacuum cleaner, Mercator personal manager bracelet, Sci-Fi LED watch, iTaste 134 E-Cigarette, Orbit dry ice washing machine, flexible 6-inch organic light emitting diode (the picture made it clear that this was a phone), vibrating ring alarm, bio polymer refrigerator, MAB computerized cleaning flies, smart stop smoking wearable device, flexible wrist computer, headbones conduction headphones.

Table 5.1: Mean (and SD) interest, coping potential, novelty, and complexity of the four products selected for the main study (Pretest).

	dry ice washing machine	bio polymer refrigerator	MAB robotic cleaning flies	personal manager bracelet
interest	6.35 (0.84)	6.62 (0.78)	6.05 (1.12)	5.93 (1.09)
coping potential	3.51 (1.60)	4.18 (1.71)	2.77 (1.36)	4.37 (1.59)
novelty	6.25 (0.97)	6.35 (0.77)	6.07 (1.04)	5.55 (0.95)
complexity	5.90 (1.28)	6.15 (1.07)	6.02 (1.07)	5.33 (1.20)

Note. Other products in the pretest were not selected because they were rated as relatively familiar (means equal or smaller than 4; vacuum cleaner, e-cigarette), relatively simple (means equal or smaller than 4; e-cigarette), relatively high coping potential (means equal or higher than 4.5; LED watch, e-cigarette, phone, ring, flexible arm computer, headphones), or relatively low interest (means lower than 5.5; vacuum cleaner, e-cigarette, stop smoking device).

Each product was evaluated in terms of *interest* (interesting, boring [reverse coded]; overall α = .88[14]), *novelty* (novel, familiar [reverse coded]; overall α = .90), *complexity* (complex, simple [reverse coded]; overall α = .92) and *coping potential* ("I feel able to understand the product", "I have a sense of what this product can be used for", "I am unsure how to try this product" [reverse coded], reliably adapted from Silvia, 2005; overall α = .93). The four products chosen for the main study were rated as interesting, but not extremely so (to avoid ceiling

[14] All alphas reported in this pretest and subsequent studies are Cronbach's alphas on all relevant items.

effects), relatively low in terms of coping potential and high on novelty and complexity (see Table 5.1). The products were: Orbit dry ice washing machine, Bio polymer refrigerator, MAB computerized cleaning flies, Mercator personal manager bracelet.[15] In the next two studies, we tested whether increasing the actual coping potential of these products would also increase interest in it.

Experiment 5.1: Similarity to a Familiar Product

In Experiment 5.1, we tested whether communicating similarity of a complex novel product to a comparable familiar product would increase interest in it. Previous research showed that communicating analogies of a new product to something known increases product comprehension (Feiereisen, Wong, & Broderick, 2008; Gregan-Paxton, Hibbard, Brunel, & Azar, 2002). Based on this, we predicted that communicating similarity of a complex novel product with a comparable familiar product would increase actual coping potential and interest in the product.

In addition, for exploratory purposes we included a measure of individual differences in innovativeness and curiosity (Curiosity and

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[15] For a picture and more information about the products, see:

- Orbit dry ice washing machine: see http://www.wired.co.uk/news/archive/2012-02/17/dry-ice-washing-machine
- MAB computerized cleaning flies: see http://electroluxdesignlab.com/en/submission/mab/
- Bio polymer refrigerator: see http://inhabitat.com/zero-energy-bio-refrigerator-cools-your-food-with-future-gel/
- Mercator personal manager bracelet: see http://www.designbuzz.com/mercator-personal-manager-besoms-a-fashion-accessory-for-the-trendy/

Exploration Inventory [CEI-II]; Kashdan et al., 2009). The Curiosity and Exploration Inventory measures the extent to which people are motivated to look for new knowledge and experiences and embrace the uncertainty and unpredictability of everyday situations. The Innovativeness scale (Goldsmith & Hofacker, 1991) measures the extent to which people are early vs. late adopters of novel products (Rogers, 2003). We predicted that high curious people and people who are often the first in knowing or owning novel products might be less affected by communicating similarity than low curious people or people who are late in knowing or owning novel product. These people are more likely to be interested in the products independent of our manipulation because the complexity is not necessarily challenging (and maybe even exciting, see Kashdan et al., 2009) and interest in novelty is part of being an innovative person (see Goldsmith & Hofacker, 1991).

Method

A total of 100 participants were recruited on MTurk (US participants only, hit rate 96%, age/gender information unavailable). First, they filled out the Curiosity and Exploration Inventory (CEI-II, Kashdan et al., 2009; e.g., "I am at my best when doing something that is complex or challenging", $\alpha = .91$), followed by the Innovativeness scale (Goldsmith & Hofacker, 1991; e.g., "In general, I am among the first in my circle of friend to buy new products or technologies", where we specified each item such that it referred to novel products or technologies; $\alpha = .83$). Then, they were randomly assigned to one of the two conditions: the similarity vs. control condition.

Participants viewed pictures from the four complex new products selected in the pretest and evaluated each product before viewing the next one. In the *control condition*, they saw the pictures with the product title: Orbit dry ice washing machine, Bio polymer refrigerator, MAB computerized cleaning flies, Mercator personal manager bracelet. In the *similarity condition*, they saw the pictures with the product title as well as similarity information: The Orbit dry ice washing machine works just like a regular washing machine, but without water and soap. / The Bio polymer refrigerator works just like a regular refrigerator, but with a special gel to keep your products cool. / The MAB computerized cleaning flies works like a regular vacuum cleaner, but with multiple small cleaning objects that move independently and automatically find dirt. / The Mercator personal manager bracelet works like your personal assistant, which you can wear as a bracelet.

Participants evaluated the products sequentially and in the same order. Below the product information, participants could complete the dependent measures. First, we measured interest in the product by asking to what extent they agreed with the following four statements about the product (reliably adapted from Silvia, 2005; $\alpha = .89$): "I think this product is interesting", "I think this product is boring" (reverse coded), "This product makes me feel curious", "I would like to try this product". Then, we measured coping potential ($\alpha = .83$), novelty ($\alpha = .71$), and complexity ($\alpha = .80$) using the same items as in the pretest. All questions could be answered on scales ranging from 1 = *not at all*, to 4

= *moderately*, to 7 = *extremely*. After evaluating all four products the study ended and participants were thanked and debriefed.

Results

In this and subsequent studies, we did not conduct null hypothesis significance tests but instead, we calculated effect sizes to measure the magnitude of effects (Trafimow & Marks, 2015; see also Lakens, 2013). Specifically, we report Glass's Δ when we compare means relative to a control condition (with the *SD* of the control condition; Experiments 5.1 and 5.2) and Cohen's *d* (with pooled *SD*) when we compare experimental groups without a control condition (Experiment 5.3). In addition, when referring to main effects or interactions, we also report eta squared (η^2) or standardized Betas (βs) where relevant.

Table 5.2: Mean (and SD/SE) interest, coping potential, novelty, and complexity as a function of condition (similarity vs. control; Experiment 5.1).

	similarity	**control**	**Glass's Δ**
interest	5.80 (0.90/0.13)	5.43 (0.97/0.14)	0.38
coping potential	4.59 (1.08/0.15)	4.14 (1.02/0.15)	0.44
novelty	5.48 (0.93/0.13)	5.30 (0.87/0.12)	0.21
complexity	4.94 (1.20/0.17)	4.87 (0.88/0.13)	0.07

Results showed that (see Table 5.2) participants in the similarity condition reported more interest in the products (M = 5.80, SD = 0.90) than participants in the control condition (M = 5.43, SD = 0.97; Glass's Δ = 0.38). In addition, participants in the similarity condition reported more coping potential with the product (M = 4.59, SD = 1.08) than participants in the control condition (M = 4.14, SD = 1.02;

Glass's Δ = 0.44). Finally, participants in the similarity vs. control condition rated the products fairly similar in terms of novelty (*M* = 5.48 *SD* = 0.93 vs. *M* = 5.30, *SD* = 0.87; Glass's Δ = 0.21) and complexity (*M* = 4.94, *SD* = 1.20 vs. *M* = 4.87, *SD* = 0.88; Glass's Δ = 0.07).

Next, we checked the effects of individual differences in curiosity and innovativeness, using standardized means for the curiosity (CEI)[16] and innovativeness scale.

Curiosity. The effect size of the interaction between similarity/control condition and curiosity on complexity was η^2 = .03, and on coping potential η^2 = .03 (other interaction effect sizes, η^2 = .01). In addition, the effect size of the main effect of curiosity on interest was η^2 = .09, and on coping potential η^2 = .05 (other curiosity main effect sizes, η^2 = .00). The effect size of the main effect of similarity/control condition on interest was η^2 = .04, and on coping potential η^2 = .04 (other similarity/control effect sizes, η^2 = .00).

To interpret the curiosity x similarity/control condition interactions, we ran a regression with similarity/control condition, low/high curiosity (standard deviation below/above the mean, following Aiken & West, 1991; for all estimated means and βs, see Table 5.3), and the interactions on coping potential and complexity. For complexity, there was a similarity/control condition x low/high curiosity interaction with β = .32 (other effects: βs between -.17 and .21). For coping potential, there was a similarity/control condition x

[16] For ease of presentation, we report results with the whole CEI-scale rather than with the embracing and stretching subscales. Results using the subscales are comparable.

low/high curiosity interaction with β = -.30, and a low/high curiosity main effect with β = .40. High curious people reported almost equal levels of coping potential in the similarity and control condition ($M_{similarity}$ = 4.64 vs. $M_{control}$ = 4.58, β = .03), whereas low curious people reported higher coping potential in the similarity condition than the control condition ($M_{similarity}$ = 4.55 vs. $M_{control}$ = 3.72; β = .39). So, for high curious people the similarity did not change their coping potential, whereas for low curious people it increased.

Table 5.3. Estimated interest, coping potential, novelty, and complexity as a function of low vs. high curiosity in the similarity vs. control condition (Experiment 5.1).

	low curiosity			high curiosity		
	similarity	control	β	similarity	control	β
interest	5.46	5.19	.14	6.13	5.67	.24
coping potential	4.55	3.72	.39	4.64	4.58	.03
novelty	5.40	5.42	-.01	5.56	5.17	.22
complexity	4.73	5.05	-.16	5.15	4.69	.22

Note: βs in the table represent the comparison of the control vs. similarity condition in the regression. βs for the main effects for low/high curiosity: interest = .25 / coping potential = .40 / novelty = -.14 / complexity = -.17. βs for the similarity/control condition x low/high curiosity interaction: interest = .09 / coping potential = .30 / novelty = .19 / complexity = .32.

Innovativeness. The effect size of the main effect of innovativeness on interest was $\eta^2 = .04$. In addition, the effect size of the main effect of similarity/control condition on interest was $\eta^2 = .03$, and on coping potential $\eta^2 = .04$. The effect sizes of the interactions between similarity/control condition and innovativeness were negligible, $\eta^2 = .00$, and so were other effect sizes, $\eta^2 <= .01$. The effect of similarity on interest was thus independent of individual differences in innovativeness.

In line with our predictions we found that communicating similarity of a complex novel product to a comparable familiar product increased interest in it. Communicating similarity also increased coping potential with the complex novel product and based on the appraisal structure of interest (Silvia, 2005), we assume that the increased interest is explained by this increased coping potential. Importantly, communicating similarity did not affect ratings of novelty or complexity of the products. Therefore, the increased coping potential cannot be explained by the product seeming more familiar or simple. This finding also suggests that the two appraisals underlying interest (novelty-complexity and coping potential) can be influenced separately and jointly but independently predict interest.

It should be noted, however, that besides communicating similarity (e.g., "works like a regular vacuum cleaner"), we also gave participants some extra information about how the complex novel products work (e.g., "works with multiple small cleaning objects that move independently and automatically find dirt"). Consequently, we cannot be certain that it is the similarity, the information, or a combination of both that drives our effect. In the next study, we therefore manipulated similarity and information separately.

Experiment 5.2: Similarity or Information

In Experiment 5.2, we presented participants with the same complex novel products as in Experiment 5.1. Next to a control condition that only gave the product title, we either communicated similarity, gave information about how it works, or both. Because all this would increase people's understanding of the product, we predicted that relative to the control condition, communicating similarity, information, and similarity + information would all increase actual coping potential and interest in the complex novel product.

We improved our manipulation in three ways. First, to more clearly communicate similarity in the similarity condition and to distinguish it from the information on how the products work, we now explicitly state "similar to" (rather than "works just like" in Experiment 5.1). In addition, we improved the information on the Orbit dry ice washing machine, such that it now explained what is new about it, like the information about the other products (i.e., "works with dry ice to clean clothes", rather than "works without water and soap", which could be interpreted as an advantage and focuses less on the innovative part). Finally, in this study, products were now presented in random order rather than in the same order.

Method

Similar to Experiment 5.1, participants (N = 200; 80 females, 120 males; M_{age} = 32.93 years, SD_{age} = 10.24; all American; education distribution was 0.5% none, 18.5% high school/GED, 35% some college, 39% bachelor's degree, 5.5% master's degree, 1.5% doctoral degree/PhD) were randomly assigned to conditions and viewed pictures of the products with a product title. In the *control condition*, this was all they saw and read. In the *similarity condition*, participants read: Orbit dry ice washing machine: similar to a regular washing machine. /

Bio polymer refrigerator: similar to a regular refrigerator. / MAB computerized cleaning flies: similar to a regular vacuum cleaner. / Mercator personal manager bracelet: similar to a personal assistant. In the *information condition*, participants read: Orbit dry ice washing machine: works with dry ice to clean your clothes. / Bio polymer refrigerator: works with a special gel to keep your products cool. / MAB computerized cleaning flies: works with multiple small cleaning objects that move independently and automatically find dirt. / Mercator personal manager bracelet: works with software in a bracelet to keep you organized. In the *similarity + information condition,* participants read both the similarity and information (i.e., combination of sentences described above). Interest (α = .90), coping potential (α = .80), novelty (α = .69), and complexity (α = .75) were measured in the same way as in Experiment 5.1.

Next, we asked some background questions. To be able to check for potential mood differences, we asked, "How do you feel right now?" on a scale 1 = *negative* to 7 = *positive*. Then, as previous experience with the products could affect coping potential independent of our manipulations, we asked, "Please indicate below whether you have seen the products you evaluated before you participated in this study?" (yes/no) for each product separately (2.5% saw the Orbit dry ice washing machine before, 7.5% the Bio polymer refrigerator, 2% the MAB computerized cleaning flies, and 5% the Mercator personal manager bracelet; excluding these participants did not affect the pattern of results so they were included in the analyses). Finally, participants reported their gender, age, nationality (American, other; open question), educational level (none, high school/GED, some college, bachelor's degree, master's degree, doctoral degree/PhD, not sure) and whether they had participated before in a similar study, in which we asked participants to evaluate the same four products (i.e., Experiment 5.1; yes/no—two participant indicated to have participated before, which did not affect the pattern of results so they were included in the analyses). After completing the background questions, participants were thanked and fully debriefed.

Results

Inspection of the mean novelty of the separate products showed that the bracelet was overall evaluated as less novel (M = 4.48) than the other products (means ranged between 5.82 and 5.83). Also, the bracelet was evaluated as less complex (M = 4.34) than the other products (means ranged between 5.18 and 5.65). In the time between the data collection of Experiments 5.1 and 5.2, several smart watches have been introduced to the market and it seems reasonable to assume that the bracelet became less novel and less complex to participants. Therefore, the bracelet is not a suitable product to test our reasoning and we excluded the ratings of this product from the main analyses. Including the bracelet in the analyses resulted in a similar, but weaker pattern of results.

Results showed that (see Table 5.4) compared to participants in the control condition (M = 5.26, SD = 1.12), participants reported more interest in the products in the similarity condition (M = 5.74, SD = 0.91; Glass's Δ = 0.43), and somewhat more in the information condition (M = 5.59, SD = 1.23; Glass's Δ = 0.29), and the similarity +

information condition (*M* = 5.59, *SD* = 1.22; Glass's Δ = 0.29). In addition, compared to participants in the control condition (*M* = 3.57, *SD* = 1.12), participants reported to have more coping potential in the similarity condition (*M* = 4.12, *SD* = 0.96; Glass's Δ = 0.49), the information condition (*M* = 4.31, *SD* = 1.20; Glass's Δ = 0.66), and the similarity + information condition (*M* = 4.15, *SD* = 0.83; Glass's Δ = 0.52).

Table 5.4: Mean (and SD/SE) interest, coping potential, novelty, and complexity as a function of condition (similarity vs. information vs. similarity + information vs. control; Experiment 5.2).

	similarity	information	similarity + information	control condition
interest	5.74	5.59	5.59	5.26
	(0.91/0.13)	(1.23/0.17)	(1.22/0.17)	(1.12/0.16)
	Δ = 0.43	Δ = 0.29	Δ = 0.29	
coping potential	4.12	4.31	4.15	3.57
	(0.96/0.14)	(1.20/0.17)	(0.83/0.12)	(1.12/0.16)
	Δ = 0.49	Δ = 0.66	Δ = 0.52	
novelty	6.08	5.98	5.68	5.53
	(0.86/0.12)	(0.97/0.14)	(1.14/0.16)	(0.78/0.11)
	Δ = 0.71	Δ = 0.58	Δ = 0.19	
complexity	5.49	5.38	5.46	5.22
	(0.98/0.14)	(1.09/0.15)	(1.02/0.14)	(1.03/0.15)
	Δ = 0.26	Δ = 0.16	Δ = 0.23	

Note: Δ = Glass's delta relative to control condition.

Interestingly, and different from Experiment 5.1, compared to participants in the control condition (*M* = 5.53, *SD* = 0.78), participants rated the products as more novel in the similarity condition (*M* = 6.08, *SD* = 0.86; Glass's Δ = 0.71) and the information condition (*M* = 5.98, *SD* = 0.97; Glass's Δ = 0.58). Novelty ratings in the similarity + information condition (*M* = 5.68, *SD* = 1.14; Glass's Δ = 0.19) were fairly similar to those in the control condition. Finally, compared to participants in the control condition (*M* = 5.22, *SD* = 1.03), participants rated the products as somewhat more complex in the similarity condition (*M* = 5.49, *SD* = 0.98, Glass's Δ = 0.26) and the similarity + information condition (*M* = 5.46, *SD* = 1.02, Glass's Δ = 0.23), while complexity ratings were fairly similar in the information condition (*M* = 5.38, *SD* = 1.09, Glass's Δ = 0.16).

Finally, compared to the control condition (*M* = 5.59, *SD* = 1.22), participants' mood was fairy similar in the similarity condition (*M* = 5.52, *SD* = 1.20, Glass's Δ = -0.06), the information condition (*M* = 5.63, *SD* = 1.18, Glass's Δ = 0.03), and the information + similarity condition (*M* = 5.78, *SD* = 1.33, Glass's Δ = 0.16).

Discussion

Taken together, the findings of Experiments 5.1 and 5.2 show that people are more interested in complex novelty when similarity to a comparable familiar option is communicated and/or information is given on how the product works. We assume that interest increased because the similarity and/or information increased actual coping potential (i.e., product-specific understanding; see also Silvia, 2005). It should be noted, however, that our manipulations could have increased perceived coping potential as well. The fact that people understand complex novelty might make them feel competent, which could also induce a readiness for complex novelty in general. Moreover, the connection to something familiar in the similarity condition could, besides product-specific understanding, also provide people with a more general safe feeling that could serve as a base for interest in complex novelty (see also Carbon et al., 2013; Gillebaart et al., 2012; Oishi et al., 2012). We will come back to this in the General Discussion.

Next, it is interesting that the strongest effects were obtained by communicating similarity. This finding is important for product developers who want to introduce their complex new product. Rather than only focusing on the innovative components of their product, they need to address the feeling that people can cope with the innovation. That this works best by explaining how the product is similar to an already known option is probably not the first thing that comes to mind when wanting to introduce a complex novel product.

In fact, when we asked an MTurk sample to imagine that they were product developers and predict what would be effective communication, they did not make choices that matched these findings. Specifically, participants (N = 50; 22 females, 28 males; M_{age} = 32.76 years, SD_{age} = 9.25; all American; Education distribution was 24% high school/GED, 32% some college, 38% bachelor's degree, 4% master's degree, 2% Doctoral degree/PhD; 4 participants participated in one of the previous studies, which did not affect the pattern of results so they were included in the analyses) were asked to evaluate the stimulus materials used in Experiment 5.2, to predict the most effective way to create interest in the product. We stated:

> Imagine you are a product developer. After an extensive development process, you created a new technological product. You are very excited about the innovativeness of the product and you can't wait to communicate to the world about it. Together with your marketing team, your aim is to create "a buzz" about your product: get attention, make people talk about your product and get them interested to find out more about it. There are of course many other new products that are being introduced. What would be an effective communication method to stand out and to be evaluated as innovative and interesting?

Then, they saw the picture of the products and saw all four text options (product title only, similarity to a familiar product, information about how it works, similarity and information together; see Experiment 5.2). They evaluated each of these four options on "People would be curious to find out more about it", "The product would attract attention", "People would be interested in the product" and "The product would be evaluated as innovative", on 7-point scales (1 = *not at all* to 7 = *extremely*). Then, they were asked to rank order the options from 1 = *most effective* to 4 = *least effective*.

We aggregated the items for the product title only (α = .96), similarity (α = .95), information (α = .93), and similarity + information (α = .96) and compared the means. Results showed that relative to only the product title (M = 4.08, SD = 1.42), the similarity text was expected to be less effective (M = 3.62, SD = 1.27, Glass's Δ = = -0.32), whereas the information text (M = 5.47, SD = 0.83, Glass's Δ = 0.98) as well as the similarity + information text (M = 5.36, SD = 0.93, Glass's Δ = 0.90) was expected to be more effective. In line with this, in the rank ordering, only 5.5% chose the similarity text as most effective, whereas 14.5% chose the product title only, 45% the information, and 25.25% the similarity and information. So, while our results showed that communicating similarity is the most effective strategy to increase interest in complex novelty, participants in this study actually think this is the least effective option.

The next study tests whether solely inducing perceived coping potential (i.e., a state in which people can tolerate complex novelty) also increases interest in complex novelty.

Experiment 5.3: Recall Coping Potential

In Experiment 5.3, we asked people to recall a situation in which they experienced high vs. low coping potential before they evaluated different recent inventions. Based on previous autobiographical recall procedures (e.g., De Hooge, Nelissen, Breugelmans, & Zeelenberg, 2011; Noordewier & Breugelmans, 2013) we reasoned that when people recall such an event, this would temporarily affect feelings of coping potential. Specifically, the recall was assumed to make memories accessible (e.g., Higgins, Rholes, & Jones 1977) through the spreading of activation of related constructs via an associative network (e.g., Berger & Fitzsimons, 2008; Collins & Loftus 1975; Neely, 1977). This temporarily actives feelings and associations related to high vs. low coping potential. Prior to evaluating the inventions, this manipulation aimed to induce a general psychological state in which people are less or more able to tolerate the unfamiliar and difficulty component of complex novelty (see also Smith & Semin, 2007). It thus constitutes a contextual manipulation of coping potential rather than a product-specific manipulation. We predicted that people who were in a state of high coping potential would be more interested in complex novel inventions than people who were in a state of low coping potential.

Method

We recruited a total of 103 participants (44 females, 59 males; M_{age} = 36.93 years, SD_{age} = 11.37) on MTurk. Settings were the same as in Experiments 5.1 and 5.2 (96% hit rate, US only). Nationality was distributed as: 101 Americans, 1 Italian, and 1 Asian. Educational level was distributed as: 11 high school/GED, 33 some college, 41 bachelor's degree, 12 master's degree, and 6 doctoral degree/PhD. Participants were randomly assigned to conditions and were asked to recall an event in which they had high vs. low coping potential. After general instructions, we explained what we meant with high [low] coping potential:

> Coping potential is the extent to which one is able to deal with an event. In some situations, people have low coping potential and in other situations, people have high coping potential. In this study, we are interested in high [low] coping potential situations. Having high

> [low] coping potential means that you have [lack] the skills, knowledge, or resources to deal with an event. So, even if [when] things are complicated, unfamiliar, or unclear, someone with high [low] coping potential is able to [cannot] deal with it. Please take a moment to think about high [low] coping potential and what this means to you.

Then, we asked participants:

> Please describe an event in your life that was complex or unfamiliar you had high [low] coping potential; you had [lacked] the skills, knowledge, or resources to deal with it; so, you could [could not] understand the situation and you were able/unable to deal with it.

Note that both in the low and the high coping potential condition, participants were asked to recall a complex or unfamiliar event. We did this to avoid that the content of the recall would be different in terms of complexity. We asked participants in the high [low] coping potential condition to recall the situation by responding to the questions: "What was complex or unfamiliar about the event?", "How did you realize that you understood [did not understand] the event?", "How did you realize that you could deal [were unable to deal] with the event?", "Which skills, knowledge, or resources did you have that enabled you [were you lacking that prevented you] to deal with the event?" Stories were diverse. Participants, for example, recalled events related to work challenges, moving house, death, illness, addiction, money issues, or accidents. Some reported examples of coping are staying calm, relying on social support, using experience (high coping potential) vs. feeling overwhelmed, not knowing what to do, and lacking experience (low coping potential).

To get a better understanding of the content of the stories and similarities or differences between conditions, two independent coders who were blind to condition, rated the material. They rated, "To what extent is the situation complex?" (r = .61; N = 97[17]), "To what extent could the person deal with the situation?" (r = .86; N = 92), "To what extent could the person influence the situation (i.e., control)?" (r = .60; N = 94) on 1 = *not at all* to 7 = *extremely*. Finally, they rated "What was the valence of the situation?" on 1 = *negative* to 7 = *positive* (r = .64; N = 94) and the type of situation (e.g., work, illness, death, relations).

After aggregating the ratings of both coders, we compared the means between high vs. low coping potential conditions. This showed that the high coping potential stories reflected a higher ability to deal with the situation (M = 5.48, SD = 0.88) than the low coping potential stories (M = 2.16, SD = 0.91; d = 3.71). In addition, the high coping potential stories reflected more controllability (M = 4.06, SD = 1.76) than the low coping potential stories (M = 2.91, SD = 1.37, d = 0.73). Also, the high coping potential stories were somewhat more positive (M = 2.81, SD = 1.04) than the low coping potential stories (M = 2.26, SD = 0.81, d = 0.59) and somewhat less complex (M = 5.45, SD = 0.92) than low coping potential stories (M = 5.66 SD = 0.85, d = -0.24).

[17] Note that there are sometimes missing data, as dimensions were only coded when information was available to accurately code it.

Finally, the distribution of the type of situations was: 26.5% work, 12.7% death, 9.8% illness, 7.8% relations, 5.9% money, 4.9% computer or technical issues, 4.9% accidents or mechanical failure, 3.9% education, 2.9% moving house, 15.7% other (e.g., addiction, low self-esteem), 4.9% missing (e.g., no clear information).

High as compared to low coping potential stories thus reflected higher ability to deal with the situation and higher controllability, which confirms that people indeed recalled situations in which they had relatively high vs. low coping potential. The differences in valence and particularly complexity were unanticipated, but compared to the other findings relatively weak.

After the recall task, we asked people to report their level of coping potential ("How would you rate your current coping potential?" from 1 = *low coping potential* to 7 = *high coping potential*). Then, the study continued to the evaluation of three recent inventions. Participants read, in random order, approximately 100-word descriptions of three inventions: 1) A temporary electronic tattoo, able to read brain wave activity, that could allow people to control machines with their mind; 2) Nano sensors for health monitoring, implants that can monitor molecules and health of cells; and 3) A cloud machine, a weather modification device that can influence the climate. For each invention, we measured interest (i.e., "This invention is interesting, this invention is boring" [reverse coded], "This invention makes me feel curious", "I would be interested in more information about this invention", α = 88; reliably adapted from Silvia, 2005) and coping potential (i.e., "This inventions is hard to understand" [reverse coded], "I have a sense of what the invention can be used for", α = .68; sufficiently reliably adapted from Silvia, 2005). All items could be answered on 7-point scales from 1 = *not at all* to 7 = *extremely*.

Finally, participants were asked various background questions. First, to be able to check for potential mood differences, we asked, "How do you feel right now?" on a scale 1 = *negative* to 7 = *positive*. Then, to be able to check whether recalling a high vs. low coping potential event was equally difficult, we stated, "We asked you to describe a recent event in your life that was complex, unfamiliar, or ambiguous with a certain level of coping potential. How difficult was it to come up with this event?". The scale ranged from 1 = *not at all* to 7 = *extremely*.

Then, as previous knowledge about the inventions could affect coping potential independent of our manipulation, we asked, "Please indicate to what extent you knew about the existence of the inventions before you participated in this study?" for each invention separately (i.e., "Did you know about...") from 1 = *not at all* to 7 = *in great detail*. For the tattoo (M = 1.18, SD = 0.68), the cloud machine (M = 1.83, SD = 1.45) and the nano sensors (M = 1.64, SD = 1.30) ratings were very low, which shows that the inventions were indeed novel to participants.

Finally, we asked participants to report their gender, age, nationality (American, other; open question), educational level (none; high school/GED; some college; bachelor's degree; master's degree; doctoral degree/PhD; not sure) and whether they had participated before in a study on coping potential and inventions (i.e., we ran a pilot a couple of month before this study; yes/no—nobody indicated to have participated before). After completing the background questions, participants were thanked and fully debriefed.

Results and Discussion

A comparison of the general coping potential measure in the high vs. low coping potential recall condition (see Table 5.5), showed that, as predicted, participants who recalled a high coping potential situation reported higher levels of coping potential *M* = 5.78, *SD* = 0.85) than people who recalled a low coping potential situation (*M* = 4.69, *SD* = 1.67; *d* = 0.82). In addition, participants in the high coping potential condition were more interested in the invention (*M* = 5.91, *SD* = 0.77) than participants in the low coping potential condition (*M* = 5.40, *SD* = 0.90; *d* = 0.61). Finally, participants in the high coping potential condition reported somewhat more coping potential with the invention (*M* = 5.15, *SD* = 0.86) than in the low coping potential condition (*M* = 4.85, *SD* = 1.07; *d* = 0.31).

Next, we checked whether controlling for differences in knowing about the invention and participants' mood changed the pattern of results. First, an ANCOVA with high vs. low coping potential condition on interest and coping potential with knowing about the inventions as covariate (mean of the three measures) showed that knowing before had an effect on coping potential with the inventions, $\eta^2 = .06$, and only weakly on interest, $\eta^2 = .02$. With knowing before in the analyses, the effect of high vs. low coping potential on interest remained, $\eta^2 = .07$, and the effect on coping potential was weak, $\eta^2 = .01$.

Table 5.5: Mean (and SD/SE) coping potential (general and with the invention) and interest as a function of recall condition (high vs. low coping potential; Experiment 5.3).

	high coping potential	low coping potential	Cohen's *d*
general coping potential	5.78 (0.85/0.12)	4.69 (1.67/0.23)	0.82
interest in invention	5.91 (0.77/0.11)	5.40 (0.90/0.12)	0.77
coping potential with invention	5.15 (0.86/0.12)	4.85 (1.07/0.15)	0.31

Next, while coping potential condition affected mood somewhat, $\eta^2 = .03$, there was still an effect of high vs. low coping potential on interest when mood was added as a covariate to the analyses, $\eta^2 = .06$, and the effect on coping potential was weak, $\eta^2 = .02$, as before. Interestingly, besides coping potential condition, mood also had an effect on interest, $\eta^2 = .07$ (other effects, $\eta^2 = .00$).

In sum, in line with our predictions we found that people who experienced more coping potential were more interested in complex novelty. While effects on specific coping potential with the invention were weaker, it seems likely that the interest was higher in the high vs. low coping potential condition because people felt more able to deal with the unfamiliar and complex component of novelty.

General Discussion

Complex novelty like new technologies can be exciting in terms of promising possibilities. At the same time, people might feel that they do not exactly grasp what the product or invention is or what it can be used for (see also Berlyne, 1971; Hoeffler, 2003; Mukherjee & Hoyer, 2000). This lack of understanding might hinder the success of complex novel products and inventions. That is, feeling interested is driven by a combination of a novelty-complexity appraisal and a coping potential appraisal (i.e., having the skills, knowledge, and resources to deal with an event; Silvia, 2005). Yet, the more complex and novel a product is, the more it interferes with people's preference to understand their environment (e.g., Aronson et al., 1968; Berlyne, 1971; Gawronski & Strack, 2012; Kay et al., 2009; Noordewier & Breugelmans, 2013; Proulx et al., 2012) and the less likely it becomes that people experience coping potential.

In agreement with this, we showed that people with relatively high coping potential are more interested in complex novelty than people with relatively low coping potential. We show this in two different ways. First, by increasing product-specific understanding of the product through communication similarity and/or providing information on how the product works, we increased *actual* coping potential (Experiments 5.1 and 5.2). Second, using an autobiographical recall procedure, we induced feelings and association related to high vs. low coping potential to affect *perceived* coping potential (Experiment 5.3).

As said, by increasing actual coping potential, we may have increased perceived coping potential as well, by making people, for instance, feel competent dealing with complex novelty in general or providing them with a familiar base to become interested in other complex novel things (see also Carbon et al., 2013; Gillebaart et al., 2012; Oishi et al., 2012). The manipulations of Experiments 5.1 and 5.2 may actually result in a mixture of actual and perceived coping potential. Future research could disentangle this by, for instance, investigating whether actual coping potential with one series of complex novel products can produce interest in another set of complex novel products. In addition, it could be investigated whether similarity or familiarity that does not directly affect product-specific understanding can increase coping potential and interest (e.g., product design that reminds people of something familiar, see also Carbon & Leder, 2005; Rindova & Petkova, 2007).

Low coping potential might be one of the reasons why many complex novel products fail (Castellion & Markham, 2012; Cierpicki et al., 2000; Schneider & Hall, 2011) as the uncertainty about its meaning or purpose might result in resistance rather than acceptance (see also Antioco & Kleijnen, 2010; Castaño et al., 2008; Hoeffler, 2003; Kleijnen et al., 2009; Oreg & Goldenberg, 2015). The finding that increasing coping potential increases interest in complex novelty fits a more general perspective on knowing states (cf. Keltner & Shiota, 2003; Silvia, 2008), that suggests that people first need to master a situation before they can appreciate it (e.g., Noordewier & Breugelmans, 2013; Noordewier, Topolinski, & Van Dijk, 2015). According to this perspective people will only approach an unknown, unpredictable, or unstructured situation when they feel they are able to cope with it.

In addition, our findings have implications for how to introduce complex novelty. Complex new products and technologies are more likely to become successful when they are introduced in settings where people have high coping potential. People are more likely to be interested in complex novelty when they are, for instance, in control or certain as compared to lacking control or feeling uncertain (Oishi et al., 2012; Rutjens et al., 2013; Van Horen & Pieters, 2013). It is also conceivable that there are situations of extreme levels of coping potential that might result in actively approaching complex novelty. For instance, when people experience boredom (Bench & Lench, 2013) or extreme levels of structure (Rutjens, Van Harreveld, & Cunningham, 2015), the unfamiliar or puzzling nature of complex novelty might be pleasant mind activation.

In addition, rather than only highlighting the innovative elements of complex new products or technologies—which is a likely and maybe even the default strategy when wanting to introduce a new product (see also the study in the discussion of Experiment 5.2)—acceptance of complex novelty might be increased by making it easier to understand. This could be accomplished by communicating similarity to a familiar product, as done in Experiments 5.1 and 5.2, but probably also via familiarity in product design (Rindova & Petkova, 2007). At the same time, it should be noted that interest does not necessarily always translate to acceptance. While interest in complex novelty is a necessary pre-condition of the adoption of complex novelty, the relation between interest and acceptance is undeniably more complex than that. Practical issues (e.g., people cannot afford it or do not need it) might lower the interest-acceptance relationship and also after people find out more about the complex novel product, they could conclude not to like it (see also Muth et al., 2015 for a connection between interest, insight, and liking). Yet, while not everybody necessarily may want to *own* complex novel products like a dry ice washing machine or computerized cleaning flies, for the development of these products, interest could contribute to support, (crowd) funding, and ultimately, success.

Finally, while product developers might worry that increasing actual or perceived coping potential might make their product seem more like other products, and thus more ordinary, this is not what we found. Our manipulations increased coping potential in Experiments 5.1, 5.2, and 5.3, but evaluations of novelty and complexity of the products and inventions remained unaffected (Experiments 5.1 and 5.3) or increased (Experiment 5.2). This suggests that the novelty-complexity and coping potential appraisals work independently (Silvia, 2005) and that it is indeed the ability to deal with complex novelty that predicts interest rather than decreased levels of novelty or complexity. Taken together, our findings suggest that people first need to feel able to cope, before they can become interested in cleaning their house using robotic cleaning flies, creating rainfall on a hot summer day with a weather modification device, or turning on their television with a brainwave tattoo.

Epilogue

The dynamics of surprise and curiosity

"The mind is an anticipatory device"

Miceli and Castelfranchi (2015; p. 3)

People constantly monitor whether reality fits their schematic representations and expectancies (e.g., Botvinick et al., 2001, Miceli & Castelfranchi, 2015). When an unexpected event is detected or when information appears to be missing, people experience surprise or curiosity (Loewenstein, 1994; Meyer et al., 1997; Silvia & Kashdan, 2009). At this point, reality does not yet make sense, which is unpleasant because it is in conflict with people's need for a predictable and coherent world (Gawronski & Strack, 2012; Miceli & Castelfranchi, 2015; Proulx et al., 2012). This unpleasantness is, however, only temporary, as people will try to make sense of the unknown and anticipate that they can resolve their lack of understanding. Following these dynamics of sense-making, I argued and showed that the subjective experience of surprise and curiosity depends on where people are in their process of dealing with the unknown.

Part 1: Surprise

The first part of this dissertation focused on surprise. Based on the temporal dynamics of sense-making, I theorized in Chapter 1 that responses to surprising events are dynamic and unfold from initial interruption (i.e., responses to the unexpectedness of an event) to cognitive mastering (i.e., responses to the valence of the event). I showed that theories and empirical evidence on surprise could be arranged onto this interruption-to-mastering timeline: Initially, surprise increases processing depth to prepare cognitive mastering. The interruption is likely to be experienced as negative and over time, responses unfold to other states depending on the nature of the stimulus. Time is thus a key factor to understand the nature of surprise and to distinguish it from its consequences.

In Chapters 2 and 3, I presented empirical support for this unfolding logic of surprise. In Chapter 2, I used autobiographical recall procedures and analyses of facial expressions over time and found that the response to a surprising event and the perception of surprise in others is initially more negative than later. This is replicated in Chapter 3, where I showed that initial facial expressions to positive surprises are more negative than later expressions. Moreover, expressions to positive and negative surprises were initially similar, but after time differentiated depending on the valence of the event. Finally, people may frown after a surprise and importantly, initial frowns were independent of the valence of the surprising target and only later turned to smiles in the case of positive surprises.

Taken together, Part 1 of this dissertation showed that to study surprise it is key to take the temporal dynamics of sense-making into account and to distinguish surprise from the state that follows it. Facial expressions are particularly suitable to reveal this unfolding, because they can capture these temporal changes.

Part 2: Curiosity

In Part 2, I focused on the dynamics of curiosity. Curiosity is the desire to know (Litman, 2005; Loewenstein, 1994; Silvia & Kashdan, 2009) and contrary to the "undecided" nature of surprise where people await further information before taking action (Scherer et al., 2004), curiosity involves exploratory motivation aimed at resolving the information-gap. In this context, time is also a key factor. Like surprise, curiosity also involves unfolding from not knowing something to knowing something. Yet, while with surprise time allows people to make sense of what has happened, with curiosity, the outcome that resolves the state is not present yet and the anticipation of finding it or being able to deal with it is the key factor. I showed that the anticipation of discovering the outcome weakens the negativity of being deprived of information. In addition, I showed that the anticipation of being able to deal with something that is not completely understood intensifies interest.

Specifically, in Chapter 4, I showed that time to the resolution of curiosity affects the subjective experience of curiosity because it determines the relative impact of not knowing vs. almost knowing what an outcome will be. When people did not expect to close their information-gap soon (long time-to-resolution), the anticipation of the resolution was weaker and not knowing affected the subjective experience of curiosity more strongly than when they expected to close their information-gap quickly (short time-to-resolution). As such, people experienced less positive affect, more discomfort, and more annoyance with lack of information when the time-to-the-resolution was long as compared to short. Moreover, when time in the long time-to-resolution situation passed, the anticipation of the resolution became stronger, positive affect increased, and discomfort and annoyance with lack of information decreased.

Finally, in Chapter 5, I focused on interest in complex novelty. I argued that people will only be motivated to explore the unknown when they think they can manage. People become more interested in complex novelty when they have a sense that they can cope with the unfamiliarity and difficulty component of complex novelty. Following this, I showed that people who had relatively high coping potential were more interested in complex novelty than people who experienced relatively low coping potential. So, products like computerized cleaning flies or Nano-technology for health monitoring were especially interesting to people who felt they understood what it is or what it is for (actual coping potential). In addition to this effect of product-specific understanding, interest in complex novelty also increased when people were in a state where they felt able to deal with the unfamiliarity and difficulty component of complex novelty (perceived coping potential).

Taken together, Part 2 of this dissertation showed that anticipation is a key factor for the subjective experience of curiosity. The closer people are to the resolution, the more they anticipate discovering new information, the more the negative feeling of deprivation is reduced. Moreover, the more people anticipate that they can deal with complex novel things, the more curious they will become.

What Happens Next?

A question that was only peripherally part of the current dissertation is what happens after surprise and curiosity are resolved. In this last section, I would like to point out some consequences of surprise and curiosity for subsequent feelings and evaluations, including what may happen when sense-making fails.

When things make sense again

When sense-making is successful, surprise and curiosity dissipate, but there may be downstream consequences for subsequent feelings and evaluations. As outlined in Part 1 of this dissertation, surprise is known to amplify the state that follows it. Based on contrast effects or transfer of arousal (Biernat, 2005; Schachter & Singer, 1962) people are, for instance, happier with unexpected than expected positive outcomes, such as when they unexpectedly gain money or receive a surprise gift

(Mellers et al., 1997; Valenzuela et al., 2009). A practical implication of this amplification potential is that people might be delighted with better-than-expected service (Oliver, 1997) and via affect-as-information (Schwarz, 1990), people might evaluate products more positive when they are introduced using surprises (e.g., in advertising, Derbaix & Vanhamme, 2003). Based on the research in the current dissertation, however, such a strategy will only be effective when people have time to make sense of it. If not, the negativity of not understanding might be used as base for judgment.

While consequences of surprise seem pretty clear, for curiosity it is more difficult to predict what will happen after the resolution. Loewenstein (1994) predicts that resolving curiosity will generally be disappointing, as the outcome cannot match the anticipation and intensity of curiosity that precedes the resolution. Yet, there may be situations that result in more positive states. First, an outcome can simply match or exceed expectancies (e.g., reading a funny end of a story or learning something really interesting), which could make it enjoyable. In addition, the positive feeling associated with resolving an information-gap might transfer to the evaluation of the target and when people predict outcomes, they might be right, which could contribute to enjoying the outcome (e.g., correctly predicting the killer in a murder mystery). Finally, when there is no clear expectation about what there is to discover (as with diversive curiosity, information search for the sake of stimulation rather than a specific answer, Berlyne, 1960), it is unlikely that outcomes are generally disappointing as people may simply enjoy what they come across. Clearly, there is more research needed to understand what determines the consequences of curiosity. This could also benefit the effectiveness of everyday use of curiosity, such as teaser advertising, cliffhangers, or movie trailers (e.g., Menon, & Soman, 2002), where it is probably not the intention that the anticipation is more exciting than the actual content.

When sense-making fails

Up until now, I have generally focused on situations where, at some point, reality makes sense again. Yet, unexpected outcomes are not always understood and information-gaps not always resolved. What happens when sense-making fails?

The failure to make sense of a surprising or unknown event will most likely result in confusion. Confusion refers to feeling unsure how to proceed in the face of an ongoing mismatch as a result of inconsistency or incoherence (D'Mello & Graesser, 2014; D'Mello, Lehman, Pekrun, & Graesser, 2014). It motivates effortful cognitive activities to resolve it (e.g., careful deliberation; D'Mello et al., 2014). Yet, when confusion persists (D'Mello et al., 2014) and people experience low or no coping potential (Silvia, 2010) it can also result in avoidance, disengagement, or moving to something different. So, an unexpected or unknown outcome results in sense-making. If this does not happen, however, people might get frustrated and, if possible, give up and disengage from the situation (D'Mello & Graesser, 2012; D'Mello et al., 2014).

It should be noted that confusion is less likely to occur with relatively simple knowledge gaps like not knowing some states in America or the contents of a box (Loewenstein, 1994; Van Dijk &

Zeelenberg, 2007). Unsuccessful sense-making in these situations may result in frustration as the not knowing state is continuously unresolved, but not in confusion as there is not really anything to be confused about (i.e., it is very clear what is missing and therefore, there is no mismatch or incoherence; see also the specific vs. diffuse information-gap in the Prologue). When people realize that the missing information will not be found, the anticipation of the resolution of curiosity will also disappear. Without this anticipation, people will most likely give up and curiosity will dissipate. As such, dealing with an unexpected or unknown outcome (e.g., Chapter 1 or 5) does not necessarily imply that people make sense of it, as they can also accept the presence of the unknown and move on.

Conclusion

The chapters in this dissertation show that people first need to master a situation of not knowing before they can appreciate it. This can occur through increased understanding, by feeling close to a resolution, or by feeling able to deal with the unknown. Surprise and curiosity are thus dynamic states that can only be fully understood by disentangling the not knowing from the (almost) knowing component. The findings in this dissertation speak to the importance of knowing and understanding the environment. Knowledge states signal a discrepancy and as long as people do not (almost) resolve this, it feels unpleasant. Only after some sense-making, it can feel good. In other words, it can be nice to be positively surprised, interesting to think about complex novelty, and enjoyable to explore the unknown—but only when it starts to make sense.

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Samenvatting

De dynamiek van verrassing en nieuwsgierigheid

Mensen houden constant in de gaten of de realiteit waar ze zich in bevinden overeenkomt met de verwachtingen en schematische representaties die ze hebben van de wereld (e.g., Botvinick et al., 2001; Miceli & Castelfranchi, 2015). Wanneer iets onverwachts wordt gedetecteerd of wanneer informatie blijkt te missen, ervaren mensen verrassing of nieuwsgierigheid (Loewenstein, 1994; Meyer et al., 1997; Silvia & Kashdan, 2009). Op het moment van dit soort discrepanties worden waargenomen is de realiteit even niet te begrijpen. Dit wordt ervaren als onplezierig omdat het de behoefte aan een voorspelbare en coherente wereld frustreert (Gawronski & Strack, 2012; Miceli & Castelfranchi, 2015; Proulx et al., 2012). Deze onplezierigheid van het "niet-weten" is echter tijdelijk. Mensen zullen de situatie proberen te begrijpen en anticiperen dat het gebrek aan informatie of begrip zal worden opgelost. In tegenstelling tot het niet-weten kan (de anticipatie van) de oplossing ervan als plezierig worden ervaren omdat het leuk kan zijn om iets nieuws te ontdekken (Berlyne, 1971; Kashdan & Silvia, 2009; Silvia & Kashdan, 2009).

Het betekenis geven aan iets dat niet begrepen wordt is dus een dynamisch proces dat zich ontvouwt van iets *niet weten* (onplezierig) naar iets *(bijna) weten* (mogelijk plezierig). In dit proefschrift laat ik zien dat de subjectieve ervaring van verrassing en nieuwsgierigheid afhankelijk is van waar mensen zich in dit proces bevinden. Door de dynamiek van betekenis geven mee te nemen in het onderzoek naar verrassing en nieuwsgierigheid blijkt het mogelijk om de niet-weten component te onderscheiden van de (bijna) weten component. Op deze manier is het mogelijk om verrassing en nieuwsgierigheid beter te begrijpen. In Deel 1 van dit proefschrift richt ik me op verrassing en het effect van de tijd die het kost om verrassende uitkomsten te begrijpen. In Deel 2 van dit proefschrift richt ik me op nieuwsgierigheid en het effect van de nabijheid van de oplossing in termen van tijd en de mate waarin mensen zich in staat voelen om te gaan met het onbekende.

Deel 1: Verrassing

Hoofdstuk 1 is een theoretische analyse op basis van de idee dat reacties op onverwachte stimuli zich temporeel ontvouwen. Wanneer mensen worden geconfronteerd met iets dat onverwacht is, ervaren ze allereerst interruptie en pas in tweede instantie begrip. Mensen reageren dus eerst op het onverwachte element van de verrassende stimulus (interruptie) en daarna pas op de valentie van deze stimulus (begrip). Theorieën en empirisch bewijs over verrassing blijken goed te passen op deze interruptie-tot-begrip tijdslijn: In eerste instantie verdiept verrassing de informatieverwerking, wat nodig is voor het latere begrip. De interruptie die in eerste instantie wordt ervaren lijkt onplezierig te zijn en pas naar mate de tijd verstrijkt, en mensen meer betekenis hebben kunnen geven aan de situatie, reageren mensen meer in lijn met de kenmerken van de stimulus (bijvoorbeeld blij wanneer de verrassende uitkomst positief is). Tijd is dus een essentiële factor om verrassing te begrijpen omdat het alleen dan kan worden onderscheiden van de gevolgen.

In Hoofdstukken 2 en 3 wordt empirisch bewijs voor het temporele ontvouwen van reacties na een verrassing gepresenteerd. In Hoofdstuk 2 beschrijf ik studies waarin autobiografische herinneringen en gezichtsexpressies worden geanalyseerd. Het blijkt dat de reactie op een verrassing en de perceptie van verrassing in anderen in eerste instantie negatiever is dan later. Dit wordt gerepliceerd in Hoofdstuk 3, waar initiële gezichtsexpressies na een positieve verrassing negatiever zijn dan latere gezichtsexpressies. Daarnaast blijkt dat gezichts-expressies na een positieve en een negatieve verrassing in het begin hetzelfde zijn en pas na enige tijd differentiëren afhankelijk van de valentie van de uitkomst. Tot slot blijkt dat de gezichtsexpressie na een verrassing mogelijk een frons bevat. Belangrijk hierbij is dat het fronzen in eerste instantie onafhankelijk is van de valentie van de verrassende uitkomst en pas later verandert in een lach in het geval van positieve verrassingen.

De hoofdstukken in Deel 1 van dit proefschrift laten zien dat het tijd kost om een verrassende uitkomst te begrijpen. Alleen als deze tijd wordt meegenomen in onderzoek naar verassing is het mogelijk om verrassing te onderscheiden van de staat die erop volgt. Het analyseren van gezichtsexpressies is uitermate geschikt om het ontvouwen van reacties te laten zien omdat het gezicht de temporele veranderingen toont.

Deel 2: Nieuwsgierigheid

In Deel 2 van dit proefschrift richt ik me op de dynamiek van nieuwsgierigheid. Nieuwsgierigheid wordt veroorzaakt door missende informatie en wordt omschreven als de behoefte om iets te weten (Litman, 2005; Loewenstein, 1994; Silvia & Kashdan, 2009). In tegenstelling tot de "onbesliste" aard van verrassing waar mensen wachten op meer informatie voordat eventueel actie wordt ondernomen (Scherer et al., 2004), bevat nieuwsgierigheid exploratieve motivatie gericht op het vinden van de missende informatie. Hierin blijkt tijd ook een belangrijke factor. Net als bij verrassing ontvouwt nieuwsgierigheid zich van iets niet weten naar iets (bijna) weten. Echter, waar tijd bij verrassing mensen in staat stelt om te begrijpen wat er is gebeurd, is tijd bij nieuwsgierigheid meer een kwestie van de nabijheid van de oplossing en de anticipatie van het ontdekken van iets nieuws.

Hoofdstuk 4 laat zien dat de tijd tot het oplossen van nieuwsgierigheid effect heeft op de subjectieve ervaring van nieuwsgierigheid. Dit komt omdat de nabijheid van de oplossing de relatieve impact van niet-weten versus bijna-weten beïnvloedt. Ik laat zien dat wanneer mensen verwachten dat het gebrek aan informatie niet snel wordt opgelost (lange tijd tot resolutie), ze een zwakkere anticipatie van de oplossing hebben en meer worden beïnvloed door het niet-weten dan wanneer mensen verwachten dat het gebrek aan informatie snel wordt opgelost (korte tijd tot de resolutie). Mensen ervaren daarom minder positieve gevoelens en meer irritatie door gebrek aan informatie wanneer de oplossing relatief lang duurt dan wanneer deze nabij is. Daarnaast blijkt dat wanneer de lange tijd tot de oplossing verstrijkt, de anticipatie van de oplossing en positieve gevoelens worden versterkt en de irritatie door gebrek aan informatie vermindert.

In Hoofdstuk 5 richt in me, tot slot, op nieuwsgierigheid en interesse in complexe nieuwe dingen. Het startpunt is dat mensen alleen het onbekende zullen exploreren wanneer ze denken dat ze dit aankunnen. Mensen zijn daarom meer geïnteresseerd in complexe nieuwe dingen wanneer ze het gevoel hebben dat ze kunnen omgaan met de onbekende of ingewikkelde component hiervan. In overeenstemming hiermee laat ik zien dat mensen die denken dat ze complexe nieuwheid aankunnen (een begrip dat in het Engels wordt aangeduid met *coping potential*) meer interesse hebben in complexe nieuwe dingen dan mensen die dit in mindere mate denken aan te kunnen. Producten of technologieën zoals bijvoorbeeld schoonmaakrobots of Nano-sensoren die processen in het lichaam kunnen meten zijn daarom vooral interessant wanneer mensen het gevoel hebben dat ze begrijpen wat het is of waar het voor bedoeld is (i.e., daadwerkelijke *coping potential*). Naast dit product-specifieke begrip blijkt interesse in complexe nieuwheid ook toe te nemen wanneer mensen een meer algemeen gevoel hebben om te kunnen gaan met onbekendheid of complexiteit (i.e., perceptie van *coping potential*). Dit hoofdstuk laat dus zien dat de introductie van nieuwe complexe producten of technologieën niet alleen gericht moet zijn op dat wat er nieuw aan is, maar ook op het bevorderen van *coping potential*.

De hoofdstukken in Deel 2 van dit proefschrift laten zien dat anticipatie een essentiële factor is in de ervaring van nieuwsgierigheid: Hoe nabijer de oplossing, hoe meer mensen anticiperen dat ze iets nieuws zullen ontdekken en hoe minder negatieve gevoelens van deprivatie een rol spelen. Daarnaast blijkt dat wanneer mensen anticiperen dat ze kunnen omgaan met complexe nieuwe dingen, ze hier nieuwsgieriger naar worden.

Conclusie

De hoofdstukken in dit proefschrift tonen aan dat mensen een situatie waarin ze iets niet weten eerst moeten begrijpen voordat ze deze kunnen waarderen. Dit kan gebeuren door middel van betekenis geven, de nabijheid van de oplossing of een gevoel om te kunnen gaan met het onbekende. Verrassing en nieuwsgierigheid zijn dus dynamische gevoelens, die alleen volledig kunnen worden begrepen door de niet-weten component te onderscheiden van de (bijna) weten component. De bevindingen in dit proefschrift tonen aan hoe belangrijk het is dat mensen de wereld om hen heen kennen en begrijpen. Verrassing en nieuwsgierigheid signaleren een discrepantie en zolang mensen dit niet (bijna) kunnen oplossen is dit vervelend. Alleen wanneer mensen in staat zijn enige betekenis te geven aan dit onbegrip bestaat de mogelijkheid dat het goed voelt. Met andere woorden, het is leuk om positief te worden verrast, interessant om na te denken over complexe nieuwe dingen en plezierig om het onbekende te exploreren—maar alleen nadat mensen het beginnen te begrijpen.

Dankwoord

Dit proefschrift gaat op vele manieren over tijd. Tijd als factor om verrassing en nieuwsgierigheid beter te begrijpen maar ook tijd om zelf betekenis te geven aan een onverwachte situatie. Tijd waarin ik af en toe dacht in een "rerun" te zitten (cf. Vonnegut's Timequake, 1997) en vooral tijd om opnieuw te kunnen ontdekken hoe leuk het is om onderzoek te doen. Ik ben veel mensen dankbaar voor het mogelijk maken van dit project en het in mij gestelde vertrouwen. In het bijzonder wil ik graag de volgende mensen noemen:

Bedankt Eric, dat je mijn promotor wilde zijn. Bedankt voor je scherpe geest, je relativeringsvermogen, en voor de deur die altijd open staat. Bedankt Naomi, voor je steun en het letterlijk en figuurlijk achter me staan. Bedankt Wilco, voor het altijd willen meedenken en dat je mijn co-promotor wilde zijn. Bedankt, Philip Spinhoven en Hanna Swaab, voor jullie initiatief en bereidheid om deze bijzondere promotie

mogelijk te maken. Bedankt, Daniel Mandel, voor het delen van je kennis.

Bedankt/thanks, Marijke en Yana, wat fijn dat jullie er zijn; it meant a lot to me to be in the craziness together. Bedankt, Marijn, voor het fijne samenwerken; je enthousiasme is aanstekelijk en motiverend. Bedankt, Leidse collega's, voor jullie ideeën en gezelligheid. Bedankt, alle andere mensen om me heen, voor de positiviteit. Bedankt, Johan en Petra, Sandra en Christian, pap en mam, Sieberen, dat jullie er altijd zijn.

Dank!

Curriculum Vitae

Marret Noordewier (Leeuwarden, 1981) completed her secondary education (VWO) in 2000 at CSG Comenius in Leeuwarden and graduated in (social) psychology at the University of Groningen in 2005. After working as a researcher at the Emmen Zoo, she went to Tilburg University and received a PhD in psychology in 2009. Then she continued working at Tilburg University as a Postdoctoral Fellow at the department of Social Psychology and as an Assistant Professor at the Communication and Information Sciences department. Since 2011, she works at Leiden University as an Assistant Professor (tenured in 2015).