Connecting the dots : playful interaction with scientific image data in repositories

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Chapter 3

Playing with images 1: Game-like interaction

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Abstract: In this chapter, we investigate video games as a platform for collection exploration, i.e. as a means to a more open-ended, exploratory interaction with a repository. We observe that video games can support both the relevant tasks, i.e. spatial navigation, and the relevant emotional state, i.e. playfulness, for collection exploration. What is more, we suggest that a more structural relationship between the game and the collection is possible: Rather than using games only as virtual spaces for navigation, we attempt to produce game logic according to the underlying graph structure of the repository. We explore these ideas on theoretical grounds and by means of a prototype game developed as a case study for the CSIDx scientific image repository. Onto-Frogger, our implemented game, is a game-like interface derived from a well-known arcade game. The chapter further documents the design, implementation and evaluation of our game. The resulting artefact is intriguing both as a product in the context of our database and as a tool to research the notion of game-like interfaces to collections.

3.1 Introduction

In most, well-maintained data repositories there is a potential for discovery. Think about it: Data repositories create opportunities for processes that are considered stimulating for discovery, such as (serendipitous) encounters with valuable items or the establishment of insightful associations between items. But if treasures lie hidden in data repositories, what tools do we need to discover them? This thesis considers tools or interfaces that can potentially empower the human user by creating opportunities for play and exploration. We advocate that play and exploration are interrelated and highly desirable acts to be facilitated by means of the interface.

There is a wide spectrum of activities that can be understood as playful or ludic. In fact, one can argue that any activity, even the most dull or tedious, can be exercised with a playful attitude, and thus be considered playful (Fullerton et al., 2008, chapter 4). Salen and Zimmerman (2004, chapter 22) propose an organization of play activities in three sets, each a subset of the previous one: Play as being playful, play as ludic activity and game play. In this chapter, we focus on the latest, i.e. on play as exercised within the formal structure of games. We consider games, more precisely, digital games, for both their entertaining value and their formal structure. Games are, after all, rule systems and we will attempt to couple their inner formal structure with aspects of the data repository. The final product should be understood as an actual game that (a) interfaces to a database and (b) channels information about the repository via its rules.

In section 3.2, we articulate why we expect video games to be relevant as interfaces for collection exploration. Our notion of collection exploration can be briefly summarized as an open-ended information activity for the sake of understanding. As we shall see, our interest in a game-like interface is developed amidst an ongoing interest in appropriating games for utilitarian purposes. Yet, we take this trend further by enforcing a tight relationship between the game and the underlying structure of the collection. In particular, we propose that a game may improve the user's mental model of the data organization, if the latter is properly encoded into the game logic.

Next to arguing on theoretical grounds, we investigate our ideas by means of an actual prototype. Specifically, we proceed with a case study for the CSIDx scientific image database described in chapter 2. The scope and context of the CSIDx repository are significant and so is the user group of the database, i.e. researchers in the life sciences. This chapter documents our path from a given database to a game concept to a final product. Section 3.3 presents Onto-Frogger, our prototype game, and the rationale behind our game concept. Section 3.4 focuses on the development of the interface of the game given the Onto-Frogger game concept. Results from user evaluations are discussed in section 3.5 while section 3.6 summarizes our conclusions on the overall process.

3.2 Motivation

This section elaborates on the idea of video games as interfaces for collection exploration. We examine the nature of the intended interaction and the ways that video games can be relevant for such an interaction. Firstly, we discuss data collections as information spaces to be navigated in a playful and engaging manner. Secondly, we examine video games as potential 'executable' visualizations, i.e. as platforms that materialize structure and existing connections rather than visualizing them.

3.2.1 Games *for* data repositories: Gaming as exploration

What does an interaction for collection exploration amount to? Interfaces for exploration differ in focus and intention from typical search interfaces to collections and may require a shift from query-based search and fact finding. Consider as an example the exploratory search paradigm: The paradigm emerged in order to address different information needs, i.e. search processes of a high degree of uncertainty of the searcher (White and Roth, 2009), and as an attempt to facilitate learning and investigation (Marchionini, 2006). An interaction for collection exploration will require a similar shift towards more open-ended activities but will be more comparable to browsing than to searching. In information science, serendipitous encounters and associations, two of the processes that seem to contribute to discovery, are traditionally linked to (semi-directed or undirected) browsing or navigation in a hypertext-ed fashion (Foster and Ford, 2003). As summarized by Zhang (2008), browsing has a high degree of interactivity and can be understood as spatial movement across attention points.

We observe that video games can support such an open-ended interaction for collection exploration. To begin with, video games are closely related to navigation, as the notion of space is a central aspect of gaming, both philosophically and technically (Newman, 2004). Technically, gaming tasks often require navigation and wayfinding in virtual, usually three-dimensional, space. In fact, when information spaces are represented as three-dimensional spaces, navigation conventions from video games are applied for navigating these new spaces. This is the case with various representations of digital collections such as libraries (Christoffel and Schmitt, 2002; Robertson, 2009) or museums (Anderson et al., 2009). We embrace the idea of collections as spaces to be navigated and note that video games can support tasks relevant for exploration, i.e. navigation.

Furthermore, video games can support the relevant emotional state for exploration. We believe that exploration requires a state of open-mindedness and even playfulness. Play is related in various ways to creativity and learning and, in the context of information systems, creativity and play may be beneficial towards serendipity and sagacity (André et al., 2009). Moreover, the field of HCI is bringing into focus positive affect, fun (Monk et al., 2002; Blythe et al., 2004) and playfulness (Kuts, 2009) as desirable aspects of interaction design. Of course, playful interfaces need not be video games, but valuable lessons can be learned from video games (Malone, 1982; Dyck et al., 2003) as good video games have shown to be very successful in user engagement. An extreme incarnation of a playful interface would take the form of an actual game: The notion of a 'game-like interface' was nicely exemplified in PSDoom (Chao, 2001), a Doom clone to administer computer processes. At the same time, various domains appropriate gaming practices in an attempt to tap engagement and attraction to video games. The serious gaming industry is developing video games for a variety of utilitarian purposes, from education to advertisement to social awareness (Susi et al., 2007; Alvarez and Michaud, 2008), while 'games with a purpose' as proposed by von Ahn (2006) attempt to convert human effort during play into productive work. Amidst such an interest in appropriating video games, we consider whether interfaces for collection exploration can be formed into video games to enhance user engagement and motivation and to benefit from the positive effect of fun and play.

3.2.2 Games *out of* data repositories: Gaming as information 'visualization'

Towards an interaction to support exploration, and, eventually, discovery, ideas and methods from the field of information visualization are relevant. Note that the primary goal of information visualization is to gain insight on data by exploiting our visual perception capacities. In the context of information visualization, exploration of an information space is related to activities that allow forming a mental model of this space, such as navigation and browsing (Spence, 2007). Similarly, Yi et al. (2008) suggest that one of the processes involved in gaining insight with visualizations is the formulation of a mental model of the data. According to Zhang (2008), information visualization can be beneficial for information retrieval as it can capture useful information that is aggregated across items, on the macro-level of the collection. In line with the aims of information visualization, we believe that collection exploration should involve a better understanding of the collection and its structure as a whole instead of looking at individual entries only. For the purposes of this paper, structure can emerge by simply modelling the collection as a network of interconnected entities.

Typically, structure as in a set of entities and their relations is abstracted to a graph. The graph, i.e. a set of vertices and edges, is in fact a non visual representation. When visualized, a graph is represented as a node-link diagram using various graph drawing algorithms such as the ones surveyed by Battista et al. (1994). The node-link diagram is not the only possible graph visualization, see e.g. matrix representations discussed by Schulz and Schumann (2006). It is, though, the most prominent graph visualization and a great amount of research is dedicated in improving graph layouts in terms of both efficiency and user satisfaction. On the other hand, interactivity has allowed for interactive graph visualizations that enable exploration and direct manipulation; Herman et al. (2000) provide an instructive survey. Interactivity and navigation, e.g. across the graph and its available paths, are essential for constructing a mental model of the graph.

We have already discussed video games in relation to navigation. If graph structures have nodes to be visited and paths to be traversed, graph structures could as well constitute a game space to be navigated. But playing a video game is not only about spatial skills: It involves a variety of challenges that activate a plethora of cognitive processes. Can we exploit these processes towards a better understanding of the structure of the collection? We realize that several common games, particularly abstract strategy board games, can be described and analysed mathematically as graphs. In reverse, we question whether game logic can be devised out of existing graph structures, such as the connections in a data collection. Essentially, we introduce a more structural relationship between the game and the collection and propose that the underlying (graph) structure of the collection should be truly incorporated into the game. To this end, structure must be properly mapped to game logic and mechanics. For example, features of the graph could be utilized to control the progress of the game, to decide upon its outcome or to score the user actions. Such a game would confront the player with the structure of the repository during game time and would require the player to actively interact and reason with the encoded structure for the needs of the game. Eventually, the game becomes a form of ‘executable’ information visualization that materializes connections rather than visualizing them.

3.3 Onto-Frogger: A game *for* and *out of* the CSIDx database

We have designed and implemented a prototype game in order to investigate the suggested link between video games and collection exploration. Our case study is based on the CSIDx scientific imaging database described in chapter 2. The scope and context of the CSIDx repository are of particular significance: The aspects of the collection that are considered worth communicating are related to the data model adopted in the collection, mainly the semantic annotation of the image data.

3.3.1 The CSIDx database as a graph

Entries in CSIDx are composite entities: They consist of image data, i.e. pixel data captured from the imaging scanner, plus semantic information, as users annotate their images with ontology terms from various life science ontologies. The existing annotations can be exploited to impose structure across the repository and establish connections across images. Specifically, we model the repository as a (undirected) graph in which every annotated image is a node. Nodes are connected with an edge when they share an annotation term and multiple annotations are reduced to a single edge. Figure 3.1 shows a snapshot of the resulting database graph. In a sense, the resulting graph constitutes the semantics of our database: A gaming activity for CSIDx should support navigation across the interconnected images and familiarize players with the derived structure.

The current database graph is a minimal representation that can be further elaborated. For example, instead of reducing multiple annotation terms to a single connection, one can devise various rules on which annotations should contribute to an edge. Similarly, the graph extraction algorithm can be further extended e.g. by assigning weights to the edges or by calculating more sophisticated similarity measures among the images. Still, the current graph is sufficient as it exemplifies our idea that assigned image annotations impose structure across the collection. Note that a different graph extraction algorithm could help bring different aspects of the collection in focus.

3.3.2 Game design phase

To allow users to literally play with the repository structure, we need to provide a game that extracts both its content and its logic from the repository. In particular, the derived graph structure of the Cyttron database (cf. subsection 3.3.1) should

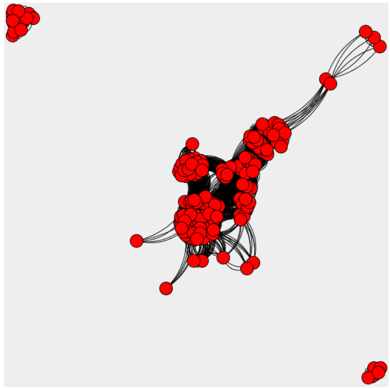


Figure 3.1: A snapshot of the CSIDx database graph (public and annotated images only) as of September 29th, 2010, rendered in the FRLayout. Nodes represent image entries and edges represent the presence of a common annotation term. The graph consists of 197 nodes, 4942 edges, 12 orphans and 3 connected components. The largest connected component has 165 nodes, 4827 edges and a graph diameter, i.e. longest shortest path, of 6.0.

be utilized to control the progress of the game, to decide upon its outcome and to score the user actions.

What kind of game would be appropriate for our purposes? As we abstract the collection to a graph structure, we sought for suitable game concepts in interplays between game tasks and graph tasks. Purely mathematical graph games played over a node-link representation do exist. For example, Bovey (2005); Bovey and Rodgers (2007) used the 'Shannon switching game' as a means to study graph comprehension across different graph layouts. However, such games will not scale up nicely to large graphs such as the ones expected in a data repository. More importantly, our focus is not on the graph visualization. On the contrary, we aim to submerge the node-link representation and communicate connections via game actions. At minimum, our game should allow 'visiting' nodes and edges of the graph in a game world. Tasks such as traversing paths and identifying neighbouring nodes are relevant tasks to be incorporated in and valued by the game logic.

As another requirement, our game needs to be simple enough to facilitate a primarily non-gaming audience. In a sense, we aim for a product that meets the characteristics of casual gaming regarding its requirements in skill and time involvement. With this in mind, we opted for adjusting an existing game concept instead of devising a new one from scratch: By appropriating a known game, we hoped to increase our chances for a successful final product thanks to a tested gameplay and/or a familiar look.

We have taken the classic arcade game Frogger (Konami Industry Co. Ltd, 1981) as a first vehicle for our own game concept. Frogger's concept (cf. Figure 3.2) seemed to be a suitable candidate for our purposes due to its popularity, simplicity and (implicit) path traversing qualities. The game is an arcade action game based on mechanic skill, i.e. timing of jumping and, in today's industry terms, would be best described as a platform game. Its interactivity can be formally narrowed down to dodging, i.e. the avoidance of moving objects, and obstacle course, i.e. the traversing of a difficult path (Wolf, 2002). To put it differently, the game requires the player to execute a valid trajectory in game space. In addition, an analogy with Frogger could lower the entry threshold for our users. The game is of iconic status and its popularity and familiar look should help our users to quickly comprehend the new game. Its simple controls and minimal storyline should aid even the non-gamer to immediately start playing.

3.3.3 Onto-Frogger, the game

Onto-Frogger, our prototype game, is a single-player, arcade style game. It borrows the game settings of the classic arcade Frogger but enhances the original action-based gameplay to include images and their annotations. In particular, the game focuses on the user annotations with ontology terms and on the connections implied by these annotations. The result is a crossover between an action/platform and a puzzle solving game. The game aims to familiarize the players with the idea that images in a (semantically enriched) collection are interconnected and to invite them to identify, predict and resolve various connections during gameplay.

In Onto-Frogger (cf. Figure 3.3), the player needs to reach a target image on the other side of a river. Arriving at the opposite bank requires the player to land successfully on image tiles, i.e. without getting drowned, and to collect enough coins on the way in order to pass the toll station on the other side. Coins are to be found on image tiles that share annotations with the target image: Every coin is an annotation term shared with the target. The objective of the game is to jump on appropriate image tiles that grant sufficient coins and to collect as many coins as possible in order to achieve a high score. Collecting multiple unique annotations (golden coins) is rewarded more points than collecting multiple instances of the same annotation (silver coins).

Technically, the so-called 'coin terms' are edges to the target image: Making a successful trajectory directly relates to visiting neighbours of the target node which can be understood as the target's immediate context in the repository.

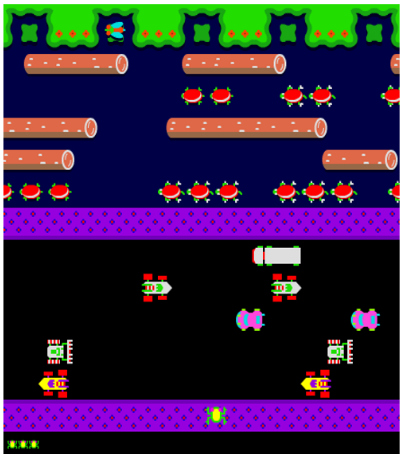


Figure 3.2: Frogger-like gameplay. The player's task is to guide a frog to its nest while avoiding a variety of threats on the way. Moving from the bottom of the screen to the top, the frog needs to cross over a busy highway, by avoiding the passing-by traffic, and then over a river, by jumping on floating objects, in order to reach the opposite bank. Technically, Frogger is an action game based on mechanic skill (timing of jumping) and, in today's industry terms, would be best described as a platform game (Frogger clone implemented by neave.com).

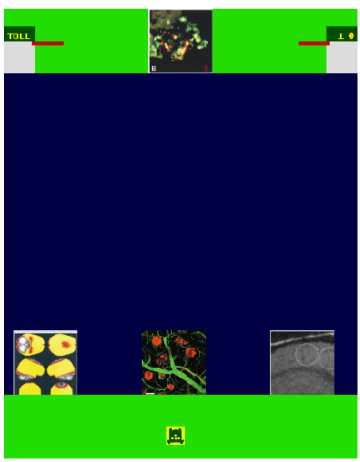


Figure 3.3: Onto-Frogger (2009), active area upon game start. The frog needs to cross the river by jumping on floating image tiles using the target image as a guide. The target image is inaccessible behind the toll station as no coins have been collected yet.

With respect to mapping graph elements to game mechanics, the game focuses on the graph edges, i.e. presence of a connection, which are translated to the game interactivity of collecting. The game also implements the traversing of a graph path as each subsequent lane consists of image tiles connected to the preceding image tile. The introduction of a coin constraint was suggested by the features of our dataset, namely a very dense graph with short distances. As a result, Onto-Frogger evolved into a more elaborate game that deviates from its original inspiration.

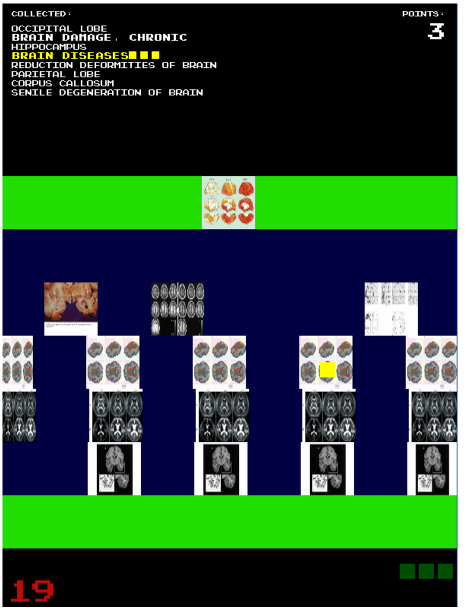
Onto-Frogger is programmed in Processing (Reas and Fry, n.d.). Processing is a subset of Java suitable for quick prototyping thanks to its excellent support for programming visuals. The graph-related functionality of the game is supported by the Java Universal Network/Graph (JUNG) framework (O'Madadhain et al., 2005). The game runs as an applet embedded in the web interface of CSIDx and it is available online for registered users of the CSIDx database.

3.4 Meeting the requirements: Refining the interface of Onto-Frogger

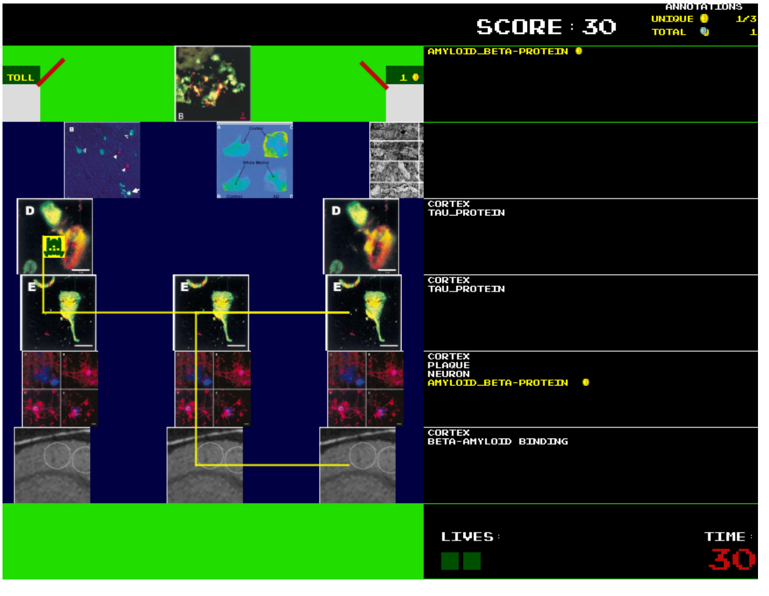
In this section, we focus on the interface of the game, i.e. on the development of a user-friendly product given a concluded game concept. In a way, we try to ensure that interface issues are not in the way of our game before questioning the validity of the game concept itself.

All in all, we believe that interface issues matter. Considering Onto-Frogger as a research prototype, it is only reasonable that we eliminate bias in responses due to interface flaws. Considering Onto-Frogger as a product, i.e. a game-like interface to a collection, its interface is central for the user experience. First, usability is a matter of concern to all video games as it can greatly affect the player's experience (Pinelle et al., 2008). Second, a game that is also an interface to a collection must provide a clear and legible information display for the data communicated. Last, the game should be straightforward enough to allow non-gamers to immediately start playing. Simplicity in controls and gameplay is directly related to the game concept but providing a self-explanatory game environment is mainly an interface issue.

A first version of Onto-Frogger's interface (prototype A, cf. Figure 3.4a) was used to examine how understandable the new game is. Two users (1 biologist, 1 computer scientist) were asked to play Onto-Frogger and figure out its rules without prior explanation. The results were discouraging: Our players did not



(a) prototype A



(b) prototype B

Figure 3.4: Prototype A vs prototype B. Collected annotations from each selected image tile are now displayed on the right panel and for each lane separately. Coins are designated on each lane and on the score summary.

Table 3.1: Major changes between prototype A and B.

type	prototype A	prototype B
layout	collected annotations and coin annotations appear on the top left part of the screen	collected annotations and coin annotations appear on the right panel of the screen
layout	collected annotations and coin annotations displayed in a term cloud	collected annotations and coin annotations displayed per lane- a HUD display summarizes the total accumulation of coins
graphics	player is a yellow square	player is a frog
graphics	yellow squares as coins	coin icons- visual distinction between silver and golden coins
narrative	-	toll station added
training	-	tutorial with in-game training

realize that a coin rule was enforced and were very frustrated when losing the game due to a lack of coins. Simply put, they were only trying to play Frogger but not Onto-Frogger. During this evaluation, we identified several interface flaws that may have obscured the significance of coins in the game. We, therefore, suggest that our players did not resolve the rule of collecting coins simply because the interface failed to place coins in focus.

In response, we re-designed the interface so that collected coins are more prominently placed. A comparison of the in-game screens of the two prototypes can be seen in Figure 3.4. Moreover, we decided to count less on the analogy with Frogger and treat Onto-Frogger as the new game that it rightfully is. Eventually, we included a complete tutorial with supportive text and storyline. The new prototype (prototype B) was subject to expert evaluations by 5 HCI literate users[1]. This evaluation was focused on the clarity of the in-game interface and tutorial, as also suggested by Pagulayan et al. (2003). Proposed improvements were further incorporated in the current version of the interface. Major differences between the two versions of the interface are summarized in Table 3.1.

A special note should be made on the look and feel of Onto-Frogger. From early on, we were aware that the resulting product should be perceived and accepted as a 'real' game. To this end, a proper look and feel of the game and consistency with gaming conventions are essential: The interface should look like a game and play like a game. Respecting industry conventions in controls is a frequent guideline in game design (Desurvire et al., 2004; Federoff, 2002) and we strive for consistency in terms of controls and feedback as well as of visual and sound design. Throughout the development of Onto-Frogger, we were fortunate to conduct expert evaluations with a game developer who reported on gamer expectations (e.g.

[1] All testers have been employed as assistant personnel for the HCI course taught in our department.

button response) and commented on the style of the game. Obviously, the look and feel of Onto-Frogger mimics that of Frogger and of arcade games in general: The visual style, game controls and soundtrack of Onto-Frogger were selected accordingly. This intention is apparent in both versions of the interface (cf. color schema and coin sounds) but prototype B improves on the graphics, within the aesthetics of the genre.

3.5 Results

3.5.1 User evaluation

The two versions of the interface were further evaluated by four novice users (4 life science students), new to both the game and database. In think-aloud sessions, the players interacted with the web interface of the database, the original Frogger game and prototypes B and A, in the given order. Prototype A was introduced as a game that may or may not have the same rules as prototype B. Both prototypes were assessed by a questionnaire including also open questions to test the players on the rules of the game.

While results are only indicative, we are pleased with quality of the current version of the interface. Overall, Prototype B is better received in terms of legibility and clarity as well as look and feel of the interface (cf. Table 3.2). With respect to the major aim of the re-design, i.e. to better support the learning of a game by means of interface improvements, we observe that prototype B allowed all players to resolve the game rules accurately. Prototype A, on the other hand, introduced confusion, particularly due to the absence of coin icons (cf. Table 3.2), but our players did not have as much difficulty as previous testers of prototype A. This observation does not render prototype B redundant since the players highly valued and often commented on the missing features. Instead, it may be an indication that prototype B allowed players to successfully internalize the game rules, a knowledge they could later use when interacting with a less supportive interface.

Interestingly enough, prototype A seems to score better that prototype B in terms of user satisfaction. Previous observations suggested that a clearer interface and, hence, a more understandable game would increase satisfaction. Our players appreciated prototype B more, visually and in terms of clarity, but found prototype A more challenging and more fun to play. The players themselves justified their preference to an increased speed of the passing tiles in prototype A. Such a feature should be easy to implement in prototype B, but it may indicate a conflict in the aims of our game: A faster pace has been in times perceived both as a welcome

Table 3.2: Relevant quotes extracted from think-aloud session (audio-recorded) and questionnaires (player id indicated as P#)

topic	quotes
interface: graphics	"a frog is better than a square" [P1], "I liked playing with a frog better than with a yellow square" [P3]
interface: graphics	"This [prototype A] is less easy to understand because there is no coin system, it only shows a few squares and they are all the same color, so it's a bit difficult to tell how many points you got and how you really got them" [P3]
gameplay: challenge	"I understood the first game quicker but at least this [prototype A] is a bit more challenging" [P3], "[prototype A] is faster... I think it's better... because it's more fun" [P1], "let the tiles come by faster because it takes a lot of time to see them all, it was better the second day" [P4]
gameplay: challenge	"if you are getting good at it, it will be fun to turn up the speed or reduce the amount of time" [P1]
mental model	"you have to understand that the tiles have connections with each other" [P1], "in how annotations are sort of linked" [P4]
mental model	"you can learn to relate pictures to text and annotations and you can relate back from annotations to pictures to get the search results you want" [P2], "what kind of annotations are required to find certain images" [P3]

challenge and as a hindrance in studying the available information. Of course, increased satisfaction could simply result from previous exposure to the game: The players, free from the load to understand the game, could now enjoy playing and would even request more challenges. Further ideas to expand gameplay with new rules or new levels are still to be considered. But the exact impact of the interface on perceived challenge is yet to be determined. Would e.g. a more adaptive interface, i.e. one that simplifies its layout as the player becomes familiar with the game, be more appropriate for our purposes?

3.5.2 Impact

Onto-Frogger (and any other game for collection exploration) is a challenging product to evaluate, due to both its hybrid character and its aims. Being a channel of information and a potential source of discovery and insight, Onto-Frogger should be evaluated with respect to the effect of its use. However, evaluating the exploratory potential of our game is a cumbersome task; the challenge is comparable to the ones faced in evaluating information visualization displays that aim to promote insight. As noted by (Saraiya et al., 2005), evaluating for insight is further complicated by the nature of the creative processes to be stimulated and may require longitudinal studies on the use of the product over time.

Anecdotal evidence, though, seems to support our ideas on the contribution of the game as an 'unconventional' interface to the image collection, especially on its impact on the user's mental model. Overall, all of our student players reflected on the collection as a connected structure and discussed the game rules in terms of establishing links between images (cf. Table 3.2). At minimum, the game does not fail to communicate connections. But the most promising potential of Onto-Frogger lies in the confrontation with the image annotation process. By interacting with the game, the players eventually reflect on the varying quality of the annotations and the different annotation strategies. Consider, for example, the following remark: One of our expert players argued that the game is inherently unfair as different images have different numbers of terms assigned to them and, hence, permit different score maxima. The observation was repeated by one of our student players, who noted that "the point system isn't completely fair". The player also observed that "sometimes only one golden coin could be collected which was needed to win" which was more difficult to achieve. The player actually proposed strategies to normalize the score but we are reluctant to correct this inherent unfairness. Another expert player complained that an obviously right image choice was not rewarded as such because the image has been annotated differently by its owner. These discussions are highly desirable in the context of our database and were entirely triggered by the game. By converting an aspect of the system into something relevant for the player, e.g. score, the game enabled the player to react on an important aspect of the system, i.e. annotations. Such exposure to the database's principles has a considerable educational potential considering that annotation of image entries is a central task for users of the CSIDx database. To date, we are still to examine the (long-term) usage of the game by users who are actively involved with the database. But, all in all, we believe that Onto-Frogger can have considerable educational capacities and can at least serve as a good introduction to our database.

3.6 Conclusion

Onto-Frogger is a product that can be examined at various levels of abstraction: As an interface, as a game, as an information channel and as an exploratory experience. At present, we can safely discuss Onto-Frogger at the interface level: Onto-Frogger has matured into a usable and legible product, whose in-game interface is, according to the requirements, explanatory of the game rules. We know less about Onto-Frogger as game: We are not sure if Onto-Frogger is a good game concept and, more importantly, if it is a proper game concept for the given graph structure. Surely, Onto-Frogger is readily accepted as a game, contains a game space that is directly derived from the graph structure and directly maps the identification of graph edges to game rules. But we have yet no means to compare alternative game concepts in terms of how well they suit our dataset. Finally, we have a glimpse on Onto-Frogger as an 'executable' information visualization and, correspondingly, as an exploratory interface: The game seems capable of materializing the collection as an interconnected structure and of exemplifying that images in a (semantically enriched) collection are interconnected. What is more, the game seems to contribute to the user's mental model of the data collection not only by materializing structure, as suggested, but also by its unindented educational quality on the topic of image annotations. In effect, playing the game confronted the players with the shortcomings of insufficiently annotated data and enabled them to reflect on a fundamental aspect of the repository, contributing to a better understanding of the collection and its underlying data organization.

As already explained (cf. section 3.4), there are various reasons why our iterations and evaluations have focused on the interface level of Onto-Frogger. Let us repeat here that we believe usability to be relevant for the gaming experience, if only for avoiding player's frustration. Of specific concern to our purposes are the notions of legibility, relevant for information display, and learnability, relevant for supporting users who are not necessarily gamers. In Onto-Frogger, where a considerable amount of information is communicated, we observed a tension between information processing and the tempo of the game. Arguably, this may be due to the game genre appropriated, i.e. arcade action game, rather than the design of the in-game interface. Nevertheless, we would like to further study the impact of the interface on the player's experience in general and on information processing in particular. Note that Onto-Frogger's in-game interface will appear 'busy' to advocates of minimalistic and integrated user interfaces for games. Then again, the game design community is torn between polemicists and proponents of non/transparent interfaces for games (Jørgensen, 2011). Still, the need for efficient information management in game interfaces is real and relevant not only to our own particular, data-oriented product but to information-dense commercial games as well.

To some extent, our emphasis on interface issues is associated to a lack of a standardized methodology. Onto-Frogger was an experiment and a research tool to tackle an unexplored territory, i.e. making games out of the graph structure of the collection for the sake of exploration. At present, we lack both a robust methodology to design such games and a framework to evaluate them. A layered evaluation approach may not be foolproof but it is, at least, a start. Note that the validity and impact of game-like interfaces for collection exploration could be properly researched only by means of a proper prototype. Then again, a 'proper' prototype must be not only a flawless interface but also a challenging and successful game. We are aware that our emphasis on eliminating interface flaws may have side-tracked us from exploring more game concepts.

Process-wise, Onto-Frogger's game concept was the outcome of creative brainstorming together with a close inspection of our dataset. An analogy with a known concept was expected to facilitate the design process but we have learned that it is the features of the graph that dominate the game design. Of course, there are multiple ways we could improve our design methodology. In the tradition of information visualization, where effective encodings of certain types of data to certain visual attributes have been proposed, we are curious if one could formalize and validate effective mappings between graph elements and game elements. Compiling a vocabulary of graph metrics and tasks versus a vocabulary of game mechanics and elements should be a manageable undertaking whereas validating the effectiveness of potential mappings will be a major challenge. On the other hand, we realize that a more user-centred approach may be more suitable for our purposes. As a matter of fact and during our conducted user tests, our testers would propose new and interesting game rules when attempting to resolve the actual game rules. We suggest that involving the players early in the game concept phase is a strategy worth exploring.

Onto-Frogger was first demonstrated in the 'Semantic Web Applications and Tools for Life Sciences' (SWAT4LS) workshop in 2009 (Kallergi and Verbeek, 2009); its development ended in 2010. In the meantime, new and relevant developments emerged. Within the context of 'gamification' (Deterding et al., 2011), Diakopoulos (2010); Diakopoulos et al. (2011) propose the concept of 'game-y [sic] infographics', i.e the amplification of infographics with gaming elements. The authors see infographics as storytelling experiences crafted by a designer and are thus interested in gaming elements as the means to a more structured, interactive storytelling experience with the data. Like our approach, the authors acknowledge that a mapping between game mechanics and visual analytics tasks is required; our approach is analogous but oriented to tasks applicable to graph structures. More importantly, we compose an entire game and game world based on our data instead of layering an infographic with game elements. At the same time, we are particularly encouraged by the concept of 'playable data' and its potential role as a valid information visualization strategy.