Hearing while feeling: Affective influences on auditory perception

Bolders, A.C.

Author: Bolders, A.C.
Title: Hearing while feeling: Affective influences on auditory perception
Issue date: 2021-02-02

2

Ups and Downs in Mood and Pitch: Mood Congruency in Auditory Perceptual Judgments

This chapter is based on: Bolders A. C., Denham, S., Stallen, P. J. M., Band, G. P. H. (in preparation). Ups and Downs in Mood and Pitch: Mood Congruency in Auditory Perceptual Judgments.

It is well established that people evaluate ambivalent stimuli in a mood congruent fashion. Happy moods promote positive evaluations, while sad moods promote negative evaluations. In the current study we investigated whether mood congruency effects extend beyond evaluative judgments to auditory perceptual judgments of pitch shift. To this end, we used an ambiguous pitch task in which the change in pitch between pairs of tones can be perceived both as ascending and as descending. We compared biases in pitch shift perception on this task between listeners in experimentally induced happy and sad moods. In Experiment 1, listeners in a sad mood judged the tone pairs more often as descending compared to listeners in a happy mood. However, pitch shift judgment bias was possibly confounded with a bias in response selection. Therefore in Experiment 2 we tested and controlled for response selection bias. Findings of Experiment 2 did not support an effect of mood on response selection bias but also not on pitch shift bias. When Experiment 1 and 2 were combined into one analysis to increase power, the pattern of results provided support for an effect of mood on pitch shift judgment that cannot be attributed to bias in response selection. It should however be noted that the effect of mood on pitch shift bias depended on strength of subjectively experienced mood. Thus, although generalizability of this study remains to be demonstrated, this study showed that not only evaluative judgments but also auditory perceptual judgments can be modulated in a mood congruent fashion.

Keywords: mood congruency, auditory perception, pitch shift, affect-as-information, missing fundamental, emotion bias.

2.1 Introduction

In a happy mood, the world looks bright, people seem friendly and birds whistle merrily. In a sad mood, however, brightness may turn into gloom, a friendly smile may be mistaken for contemptuous laughter and the cheerful twittering of birds may go unnoticed. There is ample evidence that people make judgments, such as evaluations of others' behavior or life-satisfaction in a mood congruent manner (for reviews, see Bower & Forgas, 2000; Mayer et al., 1992; Schwarz & Clore, 2007). But just how far-reaching are the consequences of our mood? To shed light on this question, we investigated whether mood congruency effects extend to auditory perceptual judgments.

According to the influential affect-as-information theory (Schwarz & Clore, 1983), individuals use their current mood as information to judge how they feel about a particular object or event (Schwarz & Clore, 2007, 1983). Recent evidence suggests that pre-existing affect not only informs evaluative judgments but also visual perceptual judgments (Riener, Stefanucci, Proffitt, & Clore, 2011; Stefanucci & Storbeck, 2009). Here we explore for the first time whether the same applies in the auditory modality.

A great deal of affective information is conveyed to us via our ears; for example, by vocal expressions (de Gelder & Vroomen, 2000) and music (Juslin & Västfjäll, 2008). Therefore we hypothesize that pre-existing affect can also inform auditory perception, resulting in mood congruent influences on auditory perceptual judgments. A recent study has indeed demonstrated mood congruency effects on the evaluation of sound; music containing both happy and sad acoustic cues is judged sadder in a sad mood (P. G. Hunter, Schellenberg, & Griffith, 2011). The current study is intended to go a step further than looking at affective evaluation, by testing for mood congruency effects on pitch shift judgments, which are qualitative judgments of sound properties.

Listeners experience tone sequences ascending in pitch as more happy than sequences descending in pitch (Collier & Hubbard, 2001). Therefore, in turn, pre-existing affect may serve as information to judge pitch shift direction of ambiguous tone sequence. For example, if listeners in a sad mood use their sad feelings to determine the direction of the pitch shift, this would bias their perception towards hearing a descending pitch shift. This bias would be strongest when the pitch shift direction is ambiguous, as affect informs judgments particularly when other, more relevant, information is inconclusive or unavailable (Schwarz & Clore, 2007).

To test for mood congruent pitch shift perception we used a task in which listeners heard a pair of tones and judged whether the pitch changed in an upward or downward direction between the first and second tone (Ladd et al., 2013; P. Schneider & Wengenroth, 2009). The pitch of both of the tones was ambiguous and chosen so that the pitch shift could be perceived both as ascending and as descending. A pitch shift judgment bias was calculated and compared between listeners in experimentally induced happy and sad moods. We expected that if mood is used as information to judge the direction of the ambiguous pitch shift, then after positive mood induction pitch shift judgment would be biased towards ascending pitch shift, while after negative mood induction, pitch shift judgment would be biased towards descending pitch shift.

2.2 Experiment 1

Method

Participants

Forty-seven participants (Age: $M = 20.1$, $SD = 2.4$, $18 - 27$ years; 10 males) with no self-reported depression or hearing problems took part for course credit or payment (€ 5). They were randomly assigned to either a happy or sad mood condition. Data from 12 participants were not included in the analyses due to technical problems (one participant), because they were aware of the hypothesis (two participants), did not comply with the mood induction procedure (two participants), scored below 60% correct on the control task (two participants), or failed to get into the desired mood state (pleasure score during the task deviating less than one point in the desired direction from neutral mood; five participants).[1] The study was approved by the ethics committee of the

[1] In footnotes, the main analyses will also be presented including participants who had a pleasure score during the task deviating less than one point in the desired direction from neutral mood.

Institute of Psychology of Leiden University. Before the start of the study each participant gave informed consent.

Mood induction and assessment

Participants were instructed to write about a mood-appropriate event in detail and to vividly imagine it. It was emphasized that their notes would be treated confidentially. They could use an autobiographical event or an example provided to them. Participants gave subjective ratings (SR) of their momentary mood by clicking on an electronic version of the 9x9 affect grid (J. A. Russell et al., 1989). They indicated pleasure on the horizontal axis (extremely unpleasant [1] to extremely pleasant [9]) and arousal on the vertical axis (extremely low arousal [1] to extremely high arousal [9]).

Pitch tasks

In the ambiguous pitch task participants were presented with pairs of harmonic complex tones with missing fundamental frequencies. Harmonic complex tones consist of frequency components, called harmonics, which are integer multiples of the (missing) fundamental frequency of the complex tone. Correspondingly, the fundamental frequency (f_0) equals the difference in frequency between adjacent harmonics (Moore, 2012). Psychophysical studies have demonstrated that when the fundamental frequency is not physically present, the pitch of a tone can be either perceived as a chord of the spectral components (f_{sp}) or as the f_0 (Ladd et al., 2013; Laguitton et al., 1998; P. Schneider et al., 2005). The tone pairs for the task were constructed in such a way that the (missing) f_0 changed in one direction from the first to the second tone, and the f_{sp} changed in the opposite direction. This is best illustrated with an example. Consider a tone pair with tone A and B. Tone A consists of a 1000, 1500 and 2000 Hz component. The pitch of tone A can be perceived as a chord of the three component frequencies (f_{sp}) or as the f_0 (500 Hz). Tone B consists of a 1200, 1600 and 2000 Hz component. Tone B thus has a higher f_{sp} than tone A, but its f_0 (400 Hz) is lower. Listeners can perceive the sequence of these tones as either ascending or descending, depending on whether they hear the pitch of the tones as the f_{sp} or f_0. For listeners who do not have an absolute preference to hear either f_0 or f_{sp}, this gives rise to ambiguous pitch shift perception (P. Schneider & Wengenroth, 2009).

The tone pairs, based on Schneider et al. (2005), were generated in MATLAB (Version 7.12.0.635, The MathWorks Inc., Natick, MA, 2011), saved as wav files (16 bit, mono, 50kHz) and played to the participants using E-prime 2 software (W. Schneider, Eschman, & Zuccolotto, 2002). Thirty-six different tone pairs (500 ms tone duration, 10 ms ramps, 250 ms silence between tones) were generated. The tone pairs were presented twice, once in one order (AB) and once in reversed order (BA), resulting in seventy-two trials.[2]

To test pitch perception ability, a control pitch task was included (Laguitton et al., 1998) with 48 different control tone pairs. The task was equal to the ambiguous pitch task except that f_0 and the f_{sp} changed in the same direction from the first to the second tone. This allowed for classification of responses as "correct" or "incorrect".[3] All sounds were presented at a comfortable level and after the practice trials (see procedure) participants were asked if the sounds were clearly audible or if sound levels had to be adjusted. None of the participants asked for an adjustment of the sound level.

In both the ambiguous pitch task and the control task, participants looked at a white fixation cross centered on the screen, which turned yellow when a tone pair was played. After listening to the tone pair, participants indicated whether the pitch of the second tone went up or down compared to the first tone (the question asked in Dutch was: *"Gaat de toonhoogte van de tweede toon ten opzichte van de eerste toon omhoog of omlaag?"*). They indicated this by clicking with the mouse on one of two buttons labeled "Upwards" ("*Omhoog*") and "Downwards" ("*Omlaag*"), located left and right from the center on the

[2] Tones of the ambiguous tone pairs consisted of two, three or four adjacent harmonics with the frequency of the upper harmonic being either 932, 1661 or 2960 Hz. These properties were the same for both tones in a tone-pair. The lowest harmonic number (the position of the harmonic in the harmonic series counting the f_0 as first harmonic) did differ between the two tones in each pair; creating a lowest harmonic number transition from the first to the second tone that was either 2 to 3; 3 to 4; 4 to 6; 7 to 9, or vice versa. Thus, in total there were 3 (numbers of harmonics) x 3 (frequencies of the upper harmonic component) x 4 (harmonic number transitions) x 2 (tone orders) = 72 different tone pairs.

[3] Control tones were constructed based on the method described by Laguitton et al. (1998) with an adapted version of the MATLAB script. For each of the seventy-two tone pairs from the ambiguous pitch-shift task, the ratio of the missing fundamental frequencies ($f0_{ratio}$ = $f0_{Tone2} / f0_{Tone1}$) and the ratio of the frequencies of the lowest harmonic components ($fmin_{ratio}$ = $fmin_{Tone2} / fmin_{Tone1}$) was computed. Next, for each of the seventy-two ambiguous pitch-shift tone pairs two control tone pairs were created, one based on the $f0_{ratio}$ and one on the $fmin_{ratio}$. This was done in the following way: The first tone of each ambiguous tone pair also served as the first tone in the control tone pairs. For the second tone in a control tone pair the frequency of each component of the first tone was multiplied with the $f0_{ratio}$ for one set of control tones pairs and with the $fmin_{ratio}$ for another set of control tone pairs. Next, 24 tone pairs from each set were selected to serve as control tone pairs: 12 with the lowest, and 12 with the highest $f0_{ratio}$; 12 with the lowest, and 12 with the highest $fmin_{ratio}$. Thus, in total there were 48 control tone pairs.

screen. Assignment of the labels to the buttons was counterbalanced across participants. Participants also indicated how certain they were of their judgment; however, data derived from this question are not presented here.

Experimental procedure

Participants were guided to a dimly lit, quiet individual test cubicle where the experimenter explained the flow of the experiment and how to use the affect grid. After inserting the earphones (Etymotic ER-4B microPro, providing 35 dB external noise attenuation) the experimenter verified whether external sounds were attenuated. Participants were seated in a comfortable chair at 50 cm from the computer monitor, where further instructions were provided.

Participants started with two practice trials with control tone pairs not further used in the experiment. Next, they proceeded to the pre-induction pitch task followed by the mood induction procedure and the post-induction pitch task. After that, participants were instructed to change their mood back to their baseline level. Participants in the sad mood-condition received a candy to help them alleviate their mood. When participants indicated that they were ready to continue, they carried out the control pitch task, followed by questionnaires that included an open question asking the participants to write down as specific as possible what they thought the goal of the experiment was (other questions not discussed here). Throughout the experiment participants rated their mood seven times on the affect grid: at the start (SR1), after the pre-induction task (SR2), halfway (SR3) and at the end (SR4) of the mood induction procedure, after the post-induction task (SR5), after mood-recovery (SR6) and after the control task (SR7).

Results

Unless indicated otherwise, we used analyses of variance (ANOVA) or t-tests. Outcome measures were screened for outliers per mood group using the three interquartile range (3IQR) criterion. The interquartile range (IQR) is the difference between the third and the first quartile (which are the quartiles between which the middle 50% of the [rank-ordered] data lies). Following the 3IQR criterion, values are considered (extreme) outliers when they lie more than $3*$IQR below the first quartile, or more than $3*$IQR above the third quartile. No outliers according to the 3IQR criterion were detected on subjective pleasure or arousal level during the task or on pre-induction or post-induction biases (see below for further explanation of how these biases were calculated).

Subjective mood experience during the pitch tasks

Subjective arousal and pleasure level averaged over ratings obtained before and after each pitch task were calculated to indicate the experienced mood during task performance. Table 2.1 shows the average ratings and standard errors during each task. There was no significant difference in pleasure, $t(33) = 1.18$, $p = .247$, or arousal, $t(33) = -.13$, $p = .894$, between the mood groups during the pre-induction task (SR1 and SR2 averaged). During the post-induction task (SR4 and SR5 averaged) the happy group experienced more pleasure, $t(33) = 19.16$ $p < .001$, and arousal, $t(33) = 3.01$, $p = .005$, than the sad group, indicating successful mood induction. During the control task (SR6 and SR7 averaged) there were no differences in pleasure, $t(33) = 0.17$, $p = .105$, or arousal, $t(33) = 0.17$, $p = .249$, between the happy and sad group, indicating a successful return to baseline mood levels.

Table 2.1: *Average subjective pleasure and arousal ratings and standard errors during each pitch task in Experiment 1.*

Affective Dimension	Mood Induction Group	Moment of measurement		
		Pre-Induction Task M (SE)	Post-induction Task M (SE)	Control Task M (SE)
Pleasure	Happy	5.72 (0.27)	7.58 (0.20)	5.86 (0.23)
	Sad	5.32 (0.20)	2.62 (0.16)	5.29 (0.25)
Arousal	Happy	5.11 (0.28)	5.44 (0.28)	4.47 (0.31)
	Sad	5.18 (0.40)	4.03 (0.38)	5.03 (0.37)

Control task

The proportion of correctly identified (unambiguous) pitch shifts in the control task did not differ between the sad ($M = 0.90$, $SE = 0.03$) and happy group ($M = 0.91$, $SE = 0.03$), $F(1,33) < 1$. This indicates that both groups had equal pitch shift identification abilities that were well above chance level.

Test of main hypothesis: Pitch shift judgment bias

For each individual the bias in pitch shift judgment was calculated from the number of upwards (n_{Up}) versus downwards (n_{Down}) judgments as follows:

$$\text{Pitch shift judgment bias} = (n_{Up} - n_{Down})/(n_{Up} + n_{Down}). \qquad (2.1)$$

Table 2.2 shows the means and standard errors of the pre-induction and (adjusted) post-induction pitch shift judgment bias per mood group. The pitch shift judgment bias did not significantly differ between the groups at pre-induction, $F(1,33) < 1$. To test the effect of mood on the pitch shift judgment bias, a one-way analysis of covariance (ANCOVA) was conducted with the pre-induction bias added as covariate to reduce error variance. Pre-induction bias was indeed significantly related to the post-induction bias, $F(1,32) = 10.76$, $p = .003$, $\eta_p^2 = 0.25$. The assumption of homogeneity-of-regression-slopes was met as indicated by a non-significant interaction between pre-induction bias and mood, which was tested in a separate model, $F(1,31) < 1$. The ANCOVA showed that the happy group had a stronger tendency than the sad group to judge the pitch shift of the tone pairs as ascending, $F(1,32) = 4.38$, $p = .044$, $\eta_p^2 = 0.12$, $MSE = 0.029$, 95% CI[0.003, 0.240].[4]

Table 2.2: *Means (and standard errors) of pre-induction and post-induction pitch shift judgment biases and standard errors per mood group of Experiment 1.*

Pitch shift judgment bias	Mood induction group	
	Happy ($N = 18$) M (SE)	Sad ($N = 17$) M (SE)
Pre-induction pitch shift judgment bias [1]	-0.057 (0.044)	-0.051 (0.045)
Post-induction pitch shift judgment bias[1,2]	-0.008 (0.040)	-0.129 (0.042)

Notes:

1. A score of 0 indicates no bias, while a score of 1 indicates full bias towards up judgments and a score of -1 indicates full bias towards down judgments.
2. Adjusted for the pre-induction pitch shift judgment bias.

[4]When participants who had a pleasure score during the task deviating less than one point in the desired direction from neutral mood were included in the analyses the effects of mood were as follows: While numerically the happy group had a stronger tendency than the sad group to judge the pitch shift of the tone pairs as ascending, the ANCOVA showed that this difference did not reach significance, $F(1,37) = 3.07$, $p = .088$, $\eta_p^2 = 0.08$, $MSE = 0.030$, 95% CI[−0.015, 0.207]. Conclusions regarding covariate and the assumptions of the ANCOVA were the same as when the participants were excluded.

Discussion

The results of Experiment 1 are in line with the hypothesis that mood congruency effects extend to judgments of auditory qualities. As was expected, participants in a happy mood showed a greater tendency to judge tone pairs as going upwards in pitch than participants in a sad mood. However, firm conclusions cannot be drawn from these results because the way in which participants indicated the direction of the pitch shift may have introduced a confounding variable. Participants indicated whether the pitch of the second tone went up or down compared to the first tone by pressing one of two buttons labelled "Upwards" and "Downwards". Participants in a happy state may have had a tendency to choose the "Upwards" response option and participants in a sad state may have had a tendency to choose the "Downwards" response option, regardless of their actual pitch shift perception. This response selection bias may thus have confounded the relationship we found between mood and pitch shift perception bias. Therefore, in Experiment 2 we set out to investigate the presence of mood induced response selection bias and to control for it. Because gender differences in pitch discrimination have been found (Rammsayer & Troche, 2012), only female participants were recruited for Experiment 2 in order to increase group homogeneity.

2.3 Experiment 2

Participants

Seventy participants (Age: $M = 19.2$, $SD = 1.8$, $17 - 27$ years; females only) with no self-reported depression or hearing problems took part for course credit or payment (€ 6.50). They were randomly assigned to either a happy or sad mood condition. Data from 16 participants were not included in the analyses due to technical problems (one participant), because they were aware of the hypothesis (one participant), did not comply with the mood induction procedure (two participants), scored below 60% correct on the control task (one participant), or failed to get into the desired mood state (pleasure score during the task deviating less than one point in the desired direction from neutral mood; eleven participants).[5]

[5] See footnote 1

Materials, mood induction, mood assessment, pitch tasks, and procedure

Materials, mood induction, mood assessment, pitch tasks, and procedure were identical to those of Experiment 1, with two exceptions. A minor difference between Experiment 1 and 2 was that in Experiment 2 both participants in the sad and the happy mood-condition received a candy after the post-induction task. This was done in order to assure that the experimenters remained blinded to the experimental conditions the participant was in until the end of the experiment.

The main difference between the experiments was the phrasing of the question regarding the pitch shift. For half of the participants the question was phrased as follows (Question 1): Was the first tone higher or lower than the second tone? (*"Was de eerste toon hoger of lager dan de tweede toon?"*). For the other half of the group the question was phrased differently (Question 2): Was the second tone higher or lower than the first tone? (*"Was de tweede toon hoger of lager dan de eerste toon?"*). All participants indicated their answer by clicking with the mouse on one of two buttons labelled "Higher" ("*Hoger*") and "Lower" ("*Lager*"), located left and right from the centre on the screen. Assignment of the labels to the buttons and question phrasing was counterbalanced across participants.

Note that for participants receiving the second question an effect of mood on response bias would be in the same direction as the hypothesized effect of mood on response selection bias. In that case response selection bias would be a positive confounding variable. For example, when answering "higher", this could be due to judging the pitch shift as going up (judging the second tone as higher), or due to a bias toward pressing the button labelled "higher". For participants receiving the second question the pitch shift bias was the reverse of the response selection bias. For example, when answering "higher" this could be due to judging the pitch shift as going down (judging the first tone as higher), or due to bias towards pressing the button labelled "higher". In this case an effect of mood on response bias would thus be in the opposite direction of the hypothesized effect of mood on response selection bias and response bias would be a negative confounding variable.

If across participants mood had an effect on pitch shift judgement but not on response selection, a main effect of mood was expected regardless of the phrasing of the pitch shift question. However, if the effect of mood was driven by response selection bias, no main effect of mood but an interaction of mood with question phrasing interaction was expected, reflecting that the effect of mood depended on how the question was phrased.

Results Experiment 2

Unless indicated otherwise, we used analyses of variance (ANOVA) or t-tests. Outcome measures were screened for outliers per mood group. No outliers according to the 3IQR criterion were detected on subjective pleasure or arousal level during the task, pre-induction or post-induction biases.

Table 2.3: *Average subjective pleasure and arousal ratings and standard errors during each pitch task in Experiment 2.*

Affective Dimension	Mood Induction Group	Moment of measurement		
		Pre-Induction Task M (SE)	Post-induction Task M (SE)	Control Task M (SE)
Pleasure	Happy	5.68 (0.20)	7.56 (0.14)	6.60 (0.20)
	Sad	5.26 (0.18)	2.48 (0.13)	5.48 (0.21)
Arousal	Happy	5.50 (0.34)	6.04 (0.29)	5.96 (0.28)
	Sad	4.66 (0.22)	3.64 (0.25)	5.10 (0.21)

Subjective mood experience during the pitch tasks

Subjective arousal and pleasure level averaged over ratings obtained before and after each pitch task were calculated to indicate the experienced mood during task performance. Table 2.3 shows the average ratings and standard errors during each task. There was no significant difference in pleasure, $t(52) = 1.57$, $p = .122$, between the mood groups during the pre-induction task (SR1 and SR2 averaged). Pre-induction arousal ratings were slightly, but significantly, larger for the happy than for the sad group, $t(52) = 2.09$, $p = .043$. During the post-induction task (SR4 and SR5 averaged) the happy group experienced more pleasure, $t(52) = 26.12$, $p < .001$, and arousal, $t(52) = 6.29$, $p < .001$, than the sad group, indicating successful mood induction. During the control task (SR6 and SR7 averaged) there were still differences, albeit smaller than during the post-induction task (see Table 2.3), in pleasure, $t(52) = 3.74$, $p < .001$, and arousal, $t(52) = 2.51$, $p = .017$, between the happy and sad group. As can be seen in the next analysis this difference was not reflected in a difference between the groups regarding performance on the control task.

Control task

The proportion of correctly identified (unambiguous) pitch shifts in the control task did not differ between the sad (M = 0.89, SE = 0.02) and happy group (M = 0.92, SE = 0.02), $F(1,50) < 1$, there was no significant effect of question phrasing, $F(1,50) < 1$, and there was no interaction between mood and question phrasing, $F(1,50) < 1$. This indicates that both mood groups had equal pitch shift identification abilities and that this did not depend on question phrasing.

Test of main hypotheses: Pitch shift judgment bias or response selection bias

The pitch shift judgment bias was calculated in the same way as in Experiment 1. The pitch shift judgment bias did not differ significantly between the groups at pre-induction, $F(1,50) < 1$, there was no significant effect of question phrasing, $F(1,50) < 1$, and there was no interaction of mood and question phrasing, $F(1,50) = 2.38$, $p = .129$, $\eta_p^2 = 0.05$. To test the effect of mood and question phrasing on the pitch shift judgment bias a two-way analysis of covariance (ANCOVA) was conducted with the pre-induction bias added as covariate to reduce error variance. Pre-induction bias was indeed significantly related to the post-induction bias, $F(1,49) = 48.65$, $p < .001$, $\eta_p^2 = 0.50$. The assumption of homogeneity-of-regression-slopes was met as indicated by non-significant interactions between pre-induction bias, mood and question phrasing, which were tested in a separate model, $F\text{s}(1,47) < 1$. As can be seen in Table 2.4, which shows the means and standard errors of the pre-induction and (adjusted) post-induction pitch shift bias, the happy group had a numerically stronger tendency than the sad group to judge the pitch shift of the tone pairs as ascending. The ANCOVA showed that this effect did not reach significance, $F(1,49) = 3.14$, $p = .083$, $\eta_p^2 = 0.06$, $MSE = 0.017$, 95% CI[−0.008, 0.134]. There was no significant interaction effect between mood and question phrasing, $F(1,49) < 1$. This indicated that effects of mood on the pitch shift judgment bias did not significantly depend on the way the question was phrased.[6]

[6] When participants who had a pleasure score during the task deviating less than one point in the desired direction from neutral mood were included in the analyses the effects of mood and question phrasing were the following: The ANCOVA showed no significant effect of mood, $F(1,60) < 1$, 95% CI[−0.051, 0.099], no significant effect of question phrasing, $F(1,60) < 1$, and no significant interaction effect between mood and question phrasing, $F(1,60) < 1$. Conclusions regarding covariate and the assumptions of the ANCOVA were the same as when the participants were excluded.

Table 2.4: *Means (and standard errors) of pre-induction and post-induction pitch shift judgment biases and standard errors per question phrasing per mood group of Experiment 2.*

Pitch shift judgment bias	Question phrasing			
	Positively confounded[1] mood induction group		Negatively confounded[1] mood induction group	
	Happy ($N = 13$) M (SE)	Sad ($N = 14$) M (SE)	Happy ($N = 12$) M (SE)	Sad ($N = 15$) M (SE)
Pre-induction pitch shift judgment bias[2]	-0.139 (0.061)	-0.034 (0.059)	0.000 (0.064)	-0.081 (0.057)
Post-induction pitch shift judgment bias[2,3]	0.013 (0.037)	-0.066 (0.035)	-0.038 (0.038)	-0.085 (0.034)

Notes:

1. The question the participants answered to indicate pitch shift judgment was phrased in such a way that the response selection bias could be either a positive or a negative confounding variable.
2. A score of 0 indicates no bias, while a score of 1 indicates full bias towards up judgments and a score of -1 indicates full bias towards down judgments.
3. Adjusted for the pre-induction pitch shift judgment bias.

Discussion

Given that the interaction effect of mood and question phrasing on pitch shift bias was not significant the data of Experiment 2 do not provide support for the concern that effects of mood are driven by response selection bias. However, while the difference in pitch shift bias between the mood groups was in the expected direction, the effect of mood was only marginally significant. Therefore, the findings of Experiment 2 did not provide conclusive evidence regarding the effect of mood on pitch shift judgment. Given that the effect of mood on pitch shift bias in Experiment 1 was rather small, insufficient power may have led to failure to detect an effect in Experiment 2. Therefore, we combined the data of Experiment 1 and 2 and carried out similar analyses as for Experiment 2. Because pitch shift bias and response selection bias were confounded in Experiment 1, we considered question phrasing in Experiment 1 as similar to question 2 in Experiment 2.

Results Experiment 1 and 2 combined

Interaction effects with experiment

Before analyzing the effects of mood and question phrasing we tested if there was an interaction of mood and experiment on pitch shift bias. The pitch shift judgment bias did not differ significantly between the groups at pre-induction, and there was no significant interaction of mood and experiment, $Fs(1,85) < 1$. To test the effect of mood and experiment on the pitch shift judgment bias a two-way analysis of covariance (ANCOVA) was conducted with the pre-induction bias added as covariate to reduce error variance. Pre-induction bias was indeed significantly related to post-induction bias, $F(1,84) = 53.54$, $p < .001$, $\eta_p^2 = 0.39$. The assumption of homogeneity-of-regression-slopes was met ($Fs(1,82) < 1$). The ANCOVA showed that the happy group had a stronger tendency than the sad group to judge the pitch shift of the tone pairs as ascending, $F(1,84) = 8.56$, $p = .004$, $\eta_p^2 = 0.09$, $MSE = 0.021$, 95% CI[0.030, 0.156]. Mood did not show a significant interaction with experiment, $F(1,84) < 1$, which indicated that the mood effect on pitch shift judgment did not depend on the experiment in a statistically significant manner and we continued analyzing the two experiments together.

Control task

The proportion of correctly identified (unambiguous) pitch shifts in the control task did not differ between the sad ($M = 0.89$, $SE = 0.02$) and happy group ($M = 0.92$, $SE = 0.02$), $F(1,85) < 1$, there was no significant effect of question phrasing, $F(1,85) < 1$, and there was no interaction between mood and question phrasing, $F(1,85) < 1$. This indicates that both mood groups had equal pitch shift identification abilities and that this did not depend on question phrasing.

Test of main hypotheses: Pitch shift judgment bias or response selection bias

The pitch shift judgment bias did not differ significantly between the groups at pre-induction, $F(1,85) < 1$, and there was no significant effect of question phrasing, $F(1,85) < 1$, or a significant interaction of mood and question phrasing, $F(1,85) = 1.83$, $p = .179$, $\eta_p^2 = 0.02$, on the pre-induction bias. To test the effect of mood and question phrasing on the pitch shift judgment bias a two-way analysis of covariance (ANCOVA) was conducted with the pre-induction bias added as covariate to reduce error variance. Pre-induction bias was indeed significantly related to post-induction bias, $F(1,84) = 53.01$, $p < .001$, $\eta_p^2 = 0.39$. The assumption of homogeneity-of-regression-slopes was met, $Fs(1,82) < 1$. The ANCOVA showed that the happy group had a stronger tendency than the sad group to judge the pitch shift of the tone pairs as ascending, $F(1,84) = 4.80$, $p = .032$, $\eta_p^2 = 0.05$, $MSE = 0.012$, 95% CI[0.007, 0.142]. There was no significant interaction effect between mood and question phrasing, $F(1,84) < 1$. This indicates that the effect of mood on the pitch shift judgment bias did not significantly depend on the way the question was phrased.[7] Figure 2.1 shows the means and 95% confidence intervals for the adjusted post-induction pitch shift bias per mood group per and type of question phrasing for Experiment 1 and 2 combined.

2.4 General Discussion

The pattern of results of Experiment 1 and 2 combined provides support for the hypothesis that mood has an effect on pitch shift judgement and that this effect is not due to response selection bias. We found a main effect of mood on pitch shift judgment, which did not depend on whether response bias was a possible positive or a negative confounding variable. The main effect reflects that sad listeners judge tone pairs with ambiguous pitch shifts more often as downwards than happy listeners. This effect cannot be attributed to response selection bias because participants indicated pitch shift direction in two different ways. For some participants response bias was a possible positive confounding variable and for others it was a possible negative confounding variable. Therefore, across participants, positive and negative confounding effects of response bias, if present, canceled each other out. The current findings of the effect of mood on pitch shift judgment fit with the affect-as-information account of mood congruent judgments. According to this theory, one's current affective state serves as information for judging objects or events. Because of the ambiguous nature of the pitch shifts in the current task, participants may have used additional affective information in their judgment of the pitch shift. As

[7]When participants who had a pleasure score during the task deviating less than one point in the desired direction from neutral mood were included in the analyses the effects of mood were the following: The ANCOVA showed no significant main effect of mood, $F(1,100) = 1.62$, $p = .206$, $\eta_p^2 = 0.05$, $MSE = 0.03$, 95% CI[−0.024, 0.111], although numerically the happy group had a slightly stronger tendency than the sad group to judge the pitch shift of the tone pairs as ascending. There was no significant effect of question phrasing and no significant interaction effect between mood and question phrasing, $Fs(1,100) < 1$. Conclusions regarding covariate and the assumptions of the ANCOVA were the same as when the participants were excluded.

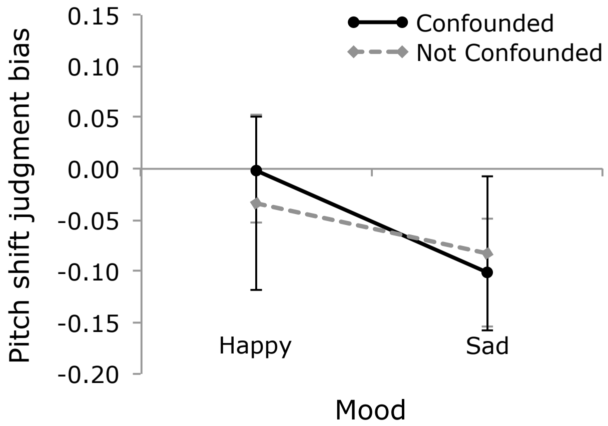

Figure 2.1: Means and 95% confidence intervals of the adjusted pitch shift bias per mood group and type of question phrasing of Experiment 1 and 2 combined.
Notes:

1. The question the participants answered to indicate pitch shift judgment was phrased in such a way that the response selection bias could be either a positive or a negative confounding variable.
2. A score of 0 indicates no bias, while a score of 1 indicates full bias towards up judgments and a score of -1 indicates full bias towards down judgments.
3. Post-induction pitch shift bias is adjusted for the pre-induction pitch shift judgment bias.

sad feelings could result from the descending pitch shifts (Collier & Hubbard, 2001), ambiguous pitch shifts in a sad mood may be more readily experienced as going downwards than upwards.

While the affect-as-information theory provides a plausible explanation, other accounts for the present findings are also worth considering. Studies have shown that selective attention, a relatively early cognitive mechanism, is facilitated for mood congruent information. Attention to rewarding information is facilitated in a positive mood (Tamir & Robinson, 2007), while attention to negative information is facilitated in a negative mood (Becker & Leinenger, 2011). In the ambiguous pitch task, attention mechanisms may have played a role in biasing the competition between the two pitch shift directions (Desimone & Duncan, 1995), enhancing perception of the mood congruent pitch shift.

Finally, Lakoff and Johnson's (1980) Conceptual Metaphor Theory provides another mechanism that may explain our findings (Crawford, 2009). According to this theory, abstract concepts such as affect are represented in a deeper, more embodied, way by means of conceptual metaphors that link these concepts to concrete sensory experience (e.g., affect is linked to vertical position, happy = up, sad = down; Crawford, 2009; Meier & Robinson, 2004). Consequently, whenever an affective feeling is activated this activates conceptual metaphors that bias perception. Several studies provide support for this idea (for a review, see Crawford, 2009). For example, Meier and Robinson (2004) showed that people are faster to detect probes in the lower than higher visual field after making a positive compared to a negative evaluation. Comparable biases have been found in the auditory domain. After judging a negative compared to a positive word, participants are faster and more accurate to categorize a low than a high tone (Weger et al., 2007). Similarly, positive or negative affect elicited by the mood induction procedure in the present study may have activated concepts of ascending or descending pitch respectively, biasing subsequent pitch shift judgments.

While the findings are in line with these theories, several limitations warrant some caution in drawing strong conclusions regarding the effect of mood on pitch shift judgment. First, the current study does not give full insight into the level at which the effects of mood on pitch shift judgment take place. As discussed above these effects may occur at an early attentional level, increasing the sensitivity towards upwards pitch shift in a happy state and to downwards pitch shift in a sad state. However, even though the analysis of Experiment 1 and 2 combined excluded a response selection bias as explanation for the pitch shift bias, the current results may also be driven by a lower decision criterion for judging a pitch shift as upwards in a happy state compared to a sad state. Thus, in terms of signal detection theory, it is not clear whether our results reflect changes in sensitivity or in response criterion. While effects of mood on sensitivity and response criterion both are relevant for perceptual decision making, future research should address this issue, for example by using a signal detection paradigm.

Second, the current study does not allow generalization of the mood effect on pitch shift bias to the general population because our main analyses included only participants that reported strong subjective mood during the task in the desired direction. In fact, there was a significant interaction effect between strength of mood (centered deviation from the midpoint (5) of the pleasure scale) during the task and mood group on pitch shift bias, $F(1, 100) = 4.80$, $p = .012$, $\eta_p^2 = 0.06$, $MSE = 0.03$. This was also reflected in the results of the analyses including both participants with weak and strong mood scores (presented in footnotes), which showed that the effects of mood did not reach significance. It is therefore desirable to replicate the current findings using a mood induction procedure that elicits sufficiently strong moods for each participant. A recent meta-analysis of mood-induction procedures (Joseph et al., 2020) showed that, although autobiographic recall is an effective procedure to elicit moods, using images of happy or sad facial expressions is particularly effective to elicit happy or sad moods. Therefore images of happy or sad facial expressions may be recommended for follow-up studies. Furthermore, another reason why generalizability may be limited is that most of the participants in Experiment 1 and all participants in Experiment 2 were female. Generalizability of the current results to male listeners may also be explored in future studies.

Third, the effect of mood on pitch shift bias is rather small and multiple other factors may contribute to this bias. For example, the pitch shift bias seems strongly determined by individual differences given that the pre-induction pitch shift bias explained a substantial amount of variance of the post-induction pitch shift bias (see partial eta squares). This may explain why the effect only becomes apparent when subjectively experienced mood is strong. Future studies may employ different ambiguous pitch shift stimuli, such as pairs of Shepard tones with frequency intervals of half an octave between them (see the Introduction chapter of this thesis), for which idiosyncratic biases may be more easily balanced out and for which strong malleability of pitch shift perception by auditory context has been demonstrated (Chambers et al., 2017). A conceptual replication of the current study using such stimuli would also be of great value to test the robustness of mood biased pitch shift judgment.

Despite its limitations, the findings of this study showed that mood biases pitch shift judgment, at least in females who experience relatively strong mood. This may be a direct perceptual effect, or a result of interactions between affect and cognition at higher levels of processing exerting top-down influence on perceptual judgment. Regardless of the exact underlying mechanism, the current findings warrant further investigation into mood congruency effects in perception, not only in vision but also in audition. Because in the current experiment the effect was limited to participants who reported strong moods, it may be of interest to investigate the effect in groups with more extreme moods, such as in individuals suffering from mood disorders. Furthermore, as mood congruent biases are suggested to play a crucial role in the expression, aetiology and maintenance of mood disorders (Beevers & Carver, 2003; Meier & Robinson, 2006), increased understanding of the pervasiveness of mood at all levels of processing could also have clinical importance. Our findings contribute to this understanding by showing for the first time that not only evaluative judgments but also auditory perceptual judgments are modulated in a mood congruent fashion.

Acknowledgments

We thank Prof. Dr. Sue Denham (Cognition Institute, Plymouth University) for helpful discussion, her collaboration in developing the study and providing the script for stimuli creation. We thank Lilian Kranenburg, Louise Wirring, Marlies Jagtenberg, and Imme van der Bent for assistance in data collection.