USING THE MAJOR AND MINOR MODE TO CREATE AFFECTIVELY–CHARGED EARCONS

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ABSTRACT

The importance of the structured fabrication of auditory (feedback) signals like earcons is common knowledge in the ICAD community. To create such structured families of earcons musical transformations like rhythm or pitch (and many others) are usually employed. However, one important transformation in Western tonal music, that of the distinction between major and minor mode, to our knowledge, has not been exploited, despite the fact that the affective connotation of the major and minor mode might be useful for research into auditory signals for affective human–computer interfaces. The present study investigated whether the transformation to major or minor mode can be used to create affectively–charged earcons for use in affective–computing research [1]. The affective–congruency effect that we obtained provides evidence that the processing of affective information can interfere with making rational, cognitive decisions. We argue that the transformation to the major or minor mode is suitable to create affectively–charged earcons and that it is important to ensure affective correspondence in computer interfaces to be able to realize optimal performance levels.

1. INTRODUCTION

The collective background of the ICAD community represents accumulated knowledge on using sound in human–computer interfaces. An important aspect therein is that auditory feedback signals should preferably be (hierarchically) structured sets of sounds, for instance, families of earcons [2, 3]. Earcons are short musical fragments that can be associated to actions or events in a computer interface. Sets, or families, of earcons are constructed using a structured method of creating increasingly complex variations of basic themes using familiar musical transformations like rhythm, pitch, timbre, or volume [4]. However, to our knowledge, an important musical transformation, that of the distinction between major and minor mode, has not been exploited. Especially for the relatively young area of affective–computing research this seems to be an unfortunate situation.

Picard [1] proposed affective computing as all computing that relates to the processing of affective information. Affective information is a type of information or stimulation that is more easily processed within an emotional framework than within a cognitive framework. The dichotomy between processing of emotionally charged and emotionally neutral information is sometimes referred to as “hot” versus “cold” cognition [5, 6]. As affective–computing research is part of human–factors investigations, one goal of affective computing can be to improve the quality of human–computer interaction by incorporating affective aspects of human–human interaction in an affectively–charged computer interface. This wealth of emotionally charged information that is often present in human–human communication, however, has not been considered for using in human–computer interfaces for a long period of time.

Note that the affectively–charged message in human–human dialogue is hardly ever the main topic of conversation and is usually carried by secondary mediums like tone of voice, facial expression, or hand gestures. This is an important insight because it provides a reason to present affectively–charged information in a different modality than the one in which the main event occurs. The present paper therefore investigates whether (families of) affect–neutral earcons can be transformed into affectively–charged variations using the affective connotation of the major and minor mode that is present in Western tonal music.

Humans are capable of perceiving and displaying an extensive range of emotions. Usually this range is divided into two distinctive sets. On the one hand there are the primary, basic emotions which are primitive responses like innate aversion or attraction and startle–based fear [7]. These emotions are often reflected in measurements of blood–volume pressure, heart rate, EEG, EMG, and the galvanic skin–response (GSR) [8, 9]. For instance, Healey and colleagues [10] created a device capable of selecting (and playing) music that was congruent with the mood of its user that the device deduced from measurements of the GSR.

The second type of emotions, on the other hand, are based on cortical, cognitive computations and include emotions like pride and frustration [7, 11]. The perception and appreciation of the affective connotation of major and minor mode also seem to be (at least) part of cognitive processing because Crowder and colleagues found that babies of around 6 months of age did not yet recognize the distinction [12] whereas Kastner and colleagues showed that children of only three years of age did recognize the conventional connotation of the major/minor distinction [13]. These findings provide evidence that the appreciation of the major/minor distinction is not innate but seems to be a cognitive phenomenon that is learned and that has a stable convention of positive affective valence associated to the major mode and a negative valence associated to the minor mode [14, 15].

The affective connotation of the major and minor mode therefore seems a good candidate to provide affectively–charged information in a computer interface, especially if that interface exploits earcons as (feedback) signals and requires that affective information is communicated via the earcons. Nevertheless, the transformation to major or minor mode is to our knowledge currently not present on the list of available musical transformations to create (extended) variations of earcons (although Blattner and colleagues [2] do hint to use "notes drawn from a single major or minor scale" to facilitate recognition and understanding, p. 26). To investigate whether the major/minor transformation can create affectively–charged variations of earcons, we exploited research paradigms from stimulus–response compatibility research [16] to explore whether the processing of affectively–charged earcons can interfere with or facilitates the processing of other affectively–charged information. We relied on indirect measures of effects of affective–information processing on cold cognition, because asking participants for affective judgments in questionnaires relies on introspection which cannot always be trusted.

The paradigms used in stimulus–response compatibility research are based on comparing performance (e.g., numbers of errors and response–time latencies) between easier, that is, more natural stimulus–response pairs and more difficult ones ([17, 18] the former usually called compatible or congruent and the latter combinations are called incompatible or incongruent). For instance, in the domain of affective–information processing De Houwer and colleagues [19] found that participants, that were instructed to say POSITIVE to nouns and NEGATIVE to adjectives, were significantly faster saying POSITIVE to the stimulus BABY than to the stimulus THIEF. In priming tasks, Fazio and colleagues [20] obtained similar findings. Despite that the words SUMMER and HONEST are semantically unrelated, Fazio found that participants showed significantly faster response times to the target of prime–target pairs like SUMMER and HONEST relative to pairs like SUMMER and THIEF. Note that in both studies [19, 20] the affective information was task–irrelevant: Participants could have carried out the task equally well without the affective information present. These findings showed that affective–information processing influenced more rationally or cognitively determined decisions.

The task that we employed in the present study was similar to the one employed by De Houwer [19]. We instructed the participants to execute Yes and No responses in a categorization task of pictures of animals and inanimate objects. Note that we presupposed that Yes–responses are associated with positive valence and that No–responses are associated with negative valence. Of course, this relationship may be questioned and can be highly task–dependent. The response "No" to the question of whether one has cancer, for example, will certainly have a positive valence.

Simultaneously with the pictures we presented our task–irrelevant affectively–charged earcons: either a C–triad in major or a C–triad in minor mode. Based on the findings of Crowder [14, 15] and others [21, 22] that the major mode is associated with positive affective valence, we expected that, for instance, the positive affective valence of an earcon in major mode would overlap (i.e., share a similarity [23]) with the affective property of a Yes response and that the positive valence of that earcon would not overlap with the valence of a No response (and v.v. for earcons in minor mode).

That is, if a participant is instructed to press a Yes–button in response to the picture of an animal and the stimulus that is presented consists of the picture of a dog accompanied by an earcon in major mode (for which response and earcon are affectively congruent), we expected responses to be quicker than for a stimulus consisting of the same picture but accompanied by an earcon in minor mode (which is an affectively incongruent trial). We tested this prediction in Experiment 1. Of course, these predictions should be independent of the response assignments. Therefore, the same predictions hold when a No–response is assigned to pictures of animals. We tested this prediction in the second experiment.

2. GENERAL METHOD

A total of 38 participants took part in both experiments. Most of them were students in psychology or cognitive science at the Radboud University. Their mean age was 23.5 years and 10 participants were male. Each participant received either € 4.50 or took part in the experiment for partial fulfillment of course requirements.

Because of the multimodal aspect of the experiment both auditory and visual stimuli were employed. The auditory stimuli were C4 and C5 major and minor triads in root position with a duration of 2500 ms, that were created by a professional sound–designer using a Roland midi module. The visual stimuli consisted of 16 black and white line–drawings of animals and inanimate objects. A study in which 24 (different) participants rated the valence of these objects showed that the mean affective valence of the animate objects did not differ from the mean valence of the inanimate objects ($t(23) = 1.284$, ns). Care was taken to ensure that all pictures were of approximately the same size when displayed on the experimental equipment. The visual targets and the earcons were presented simultaneously, because an earlier pilot study [24] showed that a stimulus–onset asynchrony of 500 ms did not influence the results.

The experiment was carried out on a Macintosh PowerMac G3 equipped with a 17 in. screen. A button box attached to the experimental computer was used to accurately synchronize the presentation of the visual and auditory stimuli and to register response–time latencies. One button was labeled "yes" and another button was labeled "no" (the actual labels were in Dutch); the order of the labeling was counterbalanced between subjects to prevent effects of preferred hand and to prevent a confound due to a possible natural tendency to assign affirmative responses to the right hand [25]. Simple stereophonic–headphones were used to present the auditory stimuli (although no stereophonic effects were used).

We used a blocked within–subjects design incorporating the factors Picture category (Animate or Inanimate) and Congruency (Affectively congruent or Affectively incongruent). Twelve trial blocks were constructed out of which four blocks reflected a congruent relation between the affective charge of the earcon and the affective valence of the responses (e.g., an earcon in major mode and a Yes response); another four blocks reflected an incongruent relationship. The remaining four blocks were included for other experimental purposes not relevant for the present study; therefore, they are not discussed in this paper. Individual trial blocks contained 32 stimuli: 8 pictures of animate objects and 8 of inanimate objects in the indicated picture–sound combinations and the same 16 pictures without sound to create a baseline condition and to prevent participants from exploiting the fixed relation between picture and sound present in each trial block. Given a set of twelve different trial blocks, the total number of trials amounted to 32 trials $\times$ 12 blocks $= 384$ trials per experiment. Within a trial block the stimuli were randomized differently for each stimulus list. The presentation order of the trial blocks over participants was according to a Latin square.

Participants were instructed to press one of two buttons to answer a question that was posed at the start of the experiment. Participants who were (randomly) assigned to the Animate–task were instructed to answer the question "Is the picture you see that of an animal?" by pressing a button labeled "yes" or "no" which implicitly associated positive responses to pictures of animals. Participants that were (randomly) assigned to the Inanimate–task were instructed to answer the question "Is the picture you see *not* that of an animal?". This question implicitly associated negative responses to pictures of animals. Participants were instructed to do this quickly and accurately; they were not explicitly instructed to ignore the sounds, but neither were they encouraged to relate the sounds to the pictures they would see and the responses they would make. Participants could practice on ten trials randomly drawn from the set of experimental trials.

Before statistical analysis, we removed error responses and response omissions from the data. These trials comprised only 1.2% of all available data points and were therefore not analyzed further. We carried out a repeated–measures ANOVA on Picture category (Animate or Inanimate) and Congruency (Affectively congruent or Affectively incongruent).

3. EXPERIMENT 1

In this experiment participants were instructed to press the Yes–button in response to a picture of an animal and to press the No–button in response to pictures of inanimate objects. We investigated whether the affective property of the response (positive and negative, respectively) overlapped with the affective valence of the earcons in major or minor mode that were presented simultaneously with the pictures.

3.1. Results & Discussion

The mean response–time latencies (and associated standard errors) for both experiments are presented in Figure 1. The left panel of the figure presents the data from Experiment 1. The overall difference in response–time latency between the congruent and incongruent condition (430 ms and 444 ms, respectively) was significant ($F(1, 20) = 6.020$, *MSE* $=$ 723.6, $p < .05$). We also found an effect of Picture category ($F(1, 20) = 34.722$, *MSE* $= 697.1$, $p < .0001$) indicating that participants were significantly faster when responding to pictures of animals (410 ms) than when they responded to pictures of inanimate objects (445 ms). Congruency and Picture category did not interact ($F < 1$).

The finding of the affective–congruency effect provides evidence that the earcons that we employed were affectively charged. If participants would not have perceived and appreciated the affective charge of the earcons, we would not have found differences in response–time latencies for the

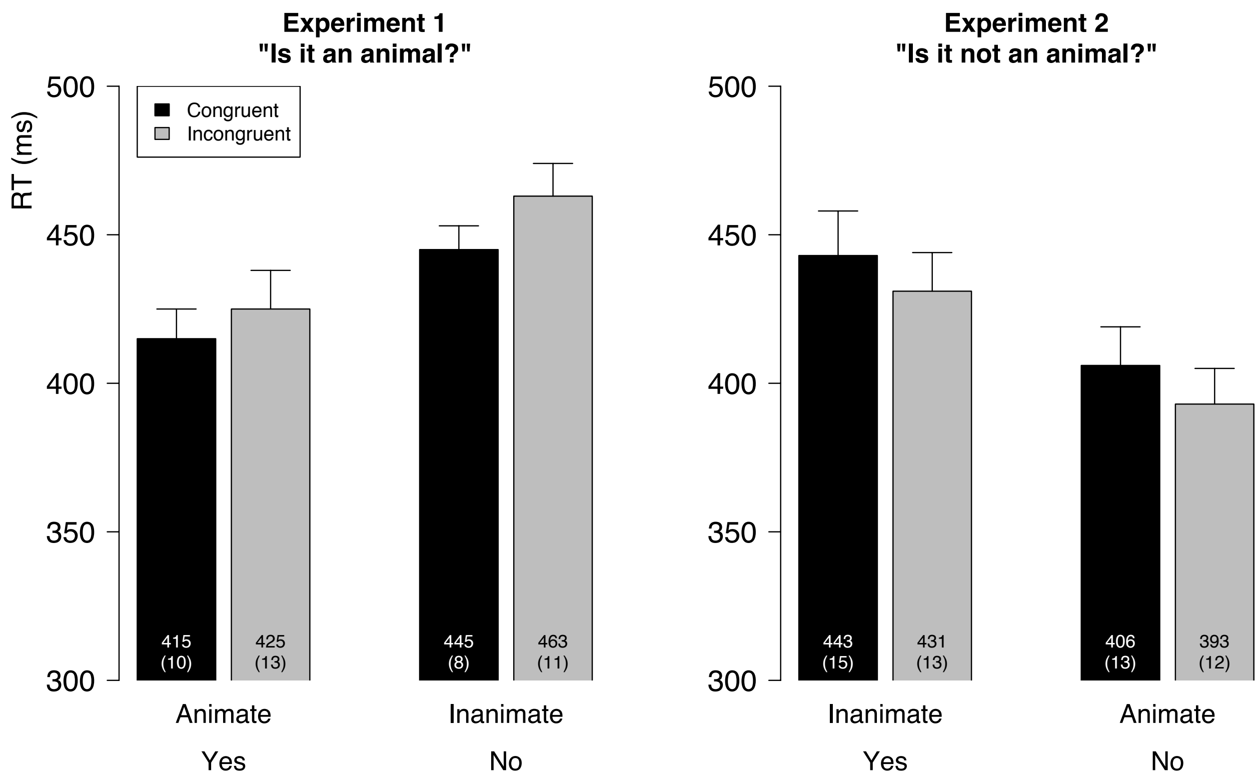

Figure 1: Mean response–time latencies (ms) for the Affectively congruent and incongruent condition for the pictures of animals and inanimate objects (Experiments 1 and 2). RT's and standard errors (in parentheses) at the bottom of each bar. The picture categories are ordered according to the Yes– and No–response assignments: In each panel the picture category on the left was assigned the Yes response. "S" signifies stimulus and "R" signifies response.

congruent and incongruent condition. Therefore, the transformation to major or minor mode seems a suitable method to create families of earcons that are capable of communicating affectively–charged information.

Note that, from this set of data, we can only tentatively conclude that the major mode was associated with positive affect (and the minor mode with negative affect) because this conclusion rests on the assumption that our Yes–responses and No–responses were positively and negatively charged, respectively, as well as the validity of Fitts' claim [17, 18] that the more natural, stereotypical combinations should be associated with the shorter response times. Nevertheless, given the stable connotation of the major and minor mode that Crowder and colleagues [14, 15, 26] and others [22] observed, we conclude that our participants most likely perceived the earcon in major mode as positively charged, whereas the earcon in minor mode was perceived having a negative connotation.

We attribute the main effect of Picture category to a processing advantage for animate items that is also observed in other studies employing the animate/inanimate dichotomy as the core distinction to differentiate between categories of stimuli [27, 28]. During evolution, the importance of the category of animate objects as food source or potentially lethal opponent may even have become hardwired into our brain [29].

4. EXPERIMENT 2

In this experiment, participants were instructed to execute negatively–charged No–responses to pictures of animals and Yes–responses to pictures of inanimate objects using a logically complex question "Is the picture you see *not* that of an animal?". This experiment was carried out to not only ensure that the experimental design was balanced with respect to the response to picture–category assignments, but to also investigate the potential impact of complex instructions on affective–information processing.

4.1. Results & Discussion

The right panel of Figure 1 shows a significant response–time difference between the congruent and incongruent condition for Experiment 2 ($F(1, 16) = 6.280$, $MSE = 446.7$, $p < .05$). Note, however, that in this experiment mean RT's were slower for the congruent condition (425 ms) and faster for the incongruent condition (412 ms). We found a significant effect of Picture category ($F(1, 16) = 42.862$, $MSE = 560.6$, $p < .0001$), again reflecting a response–time difference between mean RT's to pictures of animals (399 ms) and RT's to pictures of inanimate objects (437 ms). There was no interaction between Picture category and Congruency ($F < 1$).

The repeated finding of significant differences between response times to congruent and incongruent trials again provides evidence that the transformation to major and minor mode created affectively–charged earcons, although in this set of data the direction of the congruency effect was opposite to the direction that we observed in the first experiment. Note that obtaining reversed compatibility effects is relatively common in SRC research [30]. In our case, it is not unlikely that participants circumvented the logically–complex instruction and, for instance, strategically associated a positive charge to the negative responses and attached a negative charge to the positive responses. This strategy resulted in opposite patterns of congruency and incongruency and thus in an affective–congruency effect with a reversed direction than expected.

5. DISCUSSION

The present study investigated whether the difference in affective valence between the major and minor mode in Western tonal music could be used as an transformation of affect–neutral earcons to create affectively–charged variations for possible use in affective computer–interfaces. In a picture–categorization task we created a dimensional overlap [23] between the affective valence of the earcons and the affective property of the Yes– and No–responses that participants had to execute. The general findings can be summarized as follows. The affective–congruency effect showed that the processing of task–irrelevant affective information can interfere with the processing of task–relevant affectively–neutral information. We also conclude that affective information is encoded in a modality–neutral representation and can be compared across modalities.

In the first experiment that we carried out for this study, participants were instructed to execute positive responses to pictures of animals. We found that participants were significantly faster responding to animal pictures with earcons in major mode than to pictures of animals with earcons in minor mode (and v.v. for the pictures of the inanimate objects). That is, as predicted, in the affectively–congruent conditions participants responded quicker than in the affectively–incongruent condition. This finding shows that the processing of the task–irrelevant affective information within the earcons, particularly in the incongruent condition, interfered with the processing of the task–relevant visual information. We conclude that the major/minor transformation on the earcons resulted in affectively–charged earcons.

The data from the second experiment showed an unexpected reversal of the affective–congruency effects: participants showed longer response–time latencies for the congruent condition and shorter latencies for the incongruent condition. In this experiment, participants were instructed to execute negative responses to pictures of animals using a logically–complex instruction involving a difficult negation "Is it *not* an animal?". To explain the reversal of the congruency effect, we propose that the participants strategically recalibrated their response–selection procedure, thus introducing a congruency relation exactly opposite to the one we defined a priori. Their strategy may be related to the emphasis on the category of animals that we introduced in the instruction. An efficient method to circumvent using the complex instruction to determine the instructed response is to uncouple the default association of positive affect and Yes–responses and instead associate negative affect to the Yes–response. In simple terms, participants may have reasoned "yes, this the picture of an animal, so I have to press the No–button".

Collectively, in our view the data provide evidence that (families of) affect–neutral earcons can be transformed into variations capable of communicating affective information by using the stable affective connotation of the major and minor mode of Western tonal music [14, 21, 22]. We therefore argue to incorporate the transformation into major or minor mode in the list of possible musical transformations that can be used in structured methods to create families of (affectively–charged) earcons [2, 3, 4]. Note that the association of positive and negative with major and minor mode, respectively, is typical for (Western) tonal music. Using earcons transformed to major or minor mode in an interface may therefore limit the usage of the interface to the (West) European and American population of users. Users from Eastern or Oriental cultures may experience the affective charge in a different way, or perhaps fail to appreciate the distinction altogether, because in oriental music different tone scales are used.

The results from the present study also show that affective valence is not stored in a representation that is specific to one modality (for instance the visual modality) as one might gather from the visually and linguistically oriented studies by Fazio and colleagues [20]. This conclusion is in line with the findings by De Houwer and colleagues [31] who argue that affective–information processing is mediated by the processing of semantic information.

These findings carry two important messages for affective–computing research and human–factors research in general. The first message relates strongest to affective computing and is that affective–compatibility effects can cause performance decrements in affective human–computer interfaces that do not maintain affective correspondence between signals or events. The affective–congruency effects also show that it is possible to investigate performance in tasks employing affectively–charged stimuli and/or responses using relatively simple behavioral measurements in addition to the more complex (neuro)physiological measurements of EEG, EMG, GSR, and blood–volume pressure that are common in affective–computing research [8, 9, 10].

The second message is that, for human–factors research, it is sometimes difficult to predict the strategy that participants (often covertly) formulate to carry out the task that they are given. The reversal of the multimodal affective–congruency effect in the second experiment demonstrates that complex instructions can lead to unexpected choices by participants that can interfere with predetermined patterns of congruency. It is therefore important to measure and interpret human behavior not only within the reduced reality of the experimental laboratory but also in a realistic context because slightly different circumstances may result in completely different task–execution strategies.

In sum, the finding that the affective connotation of the major/minor distinction can be used to transmit affect using the auditory modality can be readily used by sound–designers that need to create affectively–charged earcons. Such affectively–charged earcons can be used, for instance, to more easily distinguish between the emoticons expressing positive moods and those expressing negative moods when the emoticons are displayed in the long lists that can be selected in many email or online–presence software packages. More research is needed, however, to further investigate the use of the major/minor transformation in families of earcons instead of only two individual earcons.

6. ACKNOWLEDGEMENTS

Although they were not directly involved in the writing of this manuscript, I am grateful to the advisors of my Ph.D. project: Gerard van Galen, Ab de Haan, and Ruud Meulenbroek. I would like to acknowledge Othmar Schimmel for creating the earcons. Dennis Pasveer was a great help in running the experiments.

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