PERCEPTION OF EMOTIONS IN MULTIMODAL STIMULI: THE CASE OF KNOCKING ON A DOOR

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ABSTRACT

Knocking sounds are highly expressive. In our previous studies we have demonstrated that from the sound of knocking actions alone a person can differentiate between different basic emotional states. In media production the informative power of these sounds has often been used as a storytelling device: as a way to create expectation in the audience and as a transition to different parts of the story. Despite the important role of these sounds in communication and media, little research can be found on these everyday sounds.

In this study we continue our investigation on knocking sounds with three experiments. The first two explore how the visual characteristics of a door, more specifically its colour, texture and material, presented together with a knocking action affects the perception of basic emotions. The third experiment investigates how the perception of basic emotions is affected when the door opens at different speeds after the end of the knocking action. Results show that the door visual characteristics have only small effects on the perception of emotions of the knocking action, while the door opening after the knocking action has a significant effect on the labelling of sad knocking actions, which are often categorised under fear.

1. INTRODUCTION

Knocking on a door is a very common everyday sound. Much information can be conveyed through such a simple yet expressive action ranging from hearing the way the knock is performed (e.g. closed or open palm) to recognising the emotional intention of the person knocking on the door. Understanding how communication through everyday sounds can take place, and in particular how emotions can be recognised through these sounds, is of fundamental importance when designing and synthesising everyday sounds with a specific intent to be conveyed. Media industries such as gaming, advertising and cinema, can highly benefit from technologies informed by knowledge about multi-modal human perception in order to produce the desired effects on their audiences.

Research on how emotional intentions are expressed in everyday sounds is relatively recent especially in comparison to what we know about emotions and music. A number of studies in recent years have expanded on the knowledge of human perception of emotions in aural stimuli of different nature [1–4]. Within this broader field of research, there is little exploration of the effect of knocking sounds on the emotions perceived by a listener. The aim of the present study is to build on previous research on everyday sounds and emotions as well as complementing it by focusing on audiovisual integration in audiovisual stimuli of knocking sounds. More specifically, we assess the effect that audiovisual integration has on the perception of the five basic emotional states, and in particular how audio and visual modalities, carrying congruent as well as contrasting emotional information, interact in a simple representation of a knocking action performed on a door and contribute to producing the perception of an overall emotional intention.

We conducted three experiments. The first, involving visual only stimuli of doors of different colours, materials and textures, aimed to select 5 doors that could best be associated with 5 basic emotions (anger, fear, happiness, sadness and neutral). In the second experiment knocking actions that were rated to be highly associated with the five basic emotions in our previous study are combined with the doors selected from experiment one. In this experiment we investigate how the appearance of the door combined with a knocking sound affects the overall emotional perception of the audiovisual stimuli. Finally in the third experiment, we animate the opening of the door using three different speed in order to investigate whether the door movement affects the overall emotional perception of the audiovisual stimuli.

The next sections are organised as follows: in Background (§2) the most relevant previous research and theoretical background will be reviewed; in Method (§3) a description of the three experimental designs will be presented; in Results (§4) a summary of the statistical analysis performed on the collected data and the most relevant results will be presented; finally, Discussion (§5) provides a discussion of the results in light of previous research and Conclusions (§6) summarises the work and discusses directions for further work.

2. BACKGROUND

Research has shown that everyday sounds can communicate complex information [5] and even non-musical sounds without explicit connection with everyday objects or actions, such as tone and noise complexes, can produce a emotional reactions [6]. Furthermore, research has shown

that emotions, as well as other characteristics such as material and shape of an object [3, 7, 8], are an integral part of auditory perception and are used to categorise everyday sounds [4]. From someone's footstep, for example, we can infer many characteristics of the walker including gender, type of sole, and emotional intentions [2]. In regard to knocking sounds, our recent research has shown that basic emotional intentions such as anger, fear, happiness, sadness, neutrality can be recognised from listening to knocking sounds alone [9]. Additionally, when utilising a large dataset of knocking action sounds produced by a professional Foley artist the degree of emotional intention recognition increases, showing only some confusion between the labelling of anger and fear [10]. We also showed that emotion-specific acoustic patterns in knocking sounds confirm findings from previous research in speech and music performance [2, 11, 12]. In this study we created visual representations of doors to be used in our audiovisual stimuli. The design of these images were informed by research on colour, material and texture (i.e. the roughness and pattern of the surface).

Research has shown that colours can affect our emotional perception of images and objects [13–15]. What emerges is a general agreement between most authors on a few colours (e.g. blue, red and yellow), however there is little consistency in the framework adopted for defining and categorising both the colours and the emotions associated to them. Additionally, research shows that associations between colours and emotions depend on cultural factors [16, 17] as well as other aspects such as age [18–21]. Despite this complex picture, research results are applied in many areas such as media production [22] or marketing [23]. Research on the association between materials and emotions or textures and emotions appears to be limited. Crippa et al. [24] have found that different materials can evoke emotions, even if weakly, such as satisfaction, joy, fascination, dissatisfaction and boredom. In relation to texture and emotion, Ebe and Umemuro [25] and Iosifyan and Korolkova [26] have found that people significantly associate basic emotions to different textures perceived through touch.

In the last part of this study, we explored how the door opening might affect the perception of emotion of the audiovisual stimuli. The movement of the door is therefore the new aspect, in addition to the knocks and the door visual image, that can affect the overall perception of the stimulus. While there is quite extensive research between dance movements and emotions, research on the relationship between everyday movements and emotions is lacking. Pollick et al. [27] have investigated the visual perception of affect from point-light displays of arm movements of actors performing drinking and knocking. Overall simple arm movements, while not as effective as stylized dance movements, were found to be effective by themselves in communicating affect, and that confusions among similar affects and point-light presentation contributed to the relatively low recognition rates. Gross et al. [28] studied with different methodologies the relationship between movement of knocking actions and perceived emotion. They found that some kinematic characteristics were consistent with expected movement qualities for each target emotion. For example, angry movements were energetic and forceful producing larger and faster movements, as well as longer actions. On the other hand, sad movements were exhibited diminished energy and a paucity of movement. Finally, Gerdes et al. [29] have explored audio and visual cues interact to steer attention. The study shows that emotional auditory cues guide visual spatial allocation of attention specifically to emotionally congruent pictures.

Figure 1. Example of a door image used in Experiments 1 and 2, depicting a red door with an intermediate wood texture.

3. METHOD

3.1 Experiment 1

3.1.1 Stimuli

Thirtytwo images of closed doors (600 × 600 px) combining eight colours (yellow, blue, black, grey, green, white, red, brown) and four materials + textures (metal, smooth wood, intermediate wood, rough wood) were rendered using Blender 2.90.0 in a neutral indoor environment comprising of an off-white surrounding wall, a light grey floor and basic door features – i.e. a door frame of the same material of the door and a simple metallic-grey handle (e.g. Figure 1). Six out of eight colours were chosen from the most frequently studied in previous colour and emotion research, while grey and brown were chosen as being the colours most commonly associated to a door of the selected materials.

3.1.2 Procedure

An online survey was created using the online platform PsyToolkit [30, 31]. After collecting general information about participants' age group, gender, knowledge about color theory and color blindness, participants were presented with the 32 images of doors. The order of presentation of the doors was randomised between participants.

For each image, participants were asked to choose the emotional state the door evoked in them between Anger, Happiness, Neutral, Sadness and Fear. Participants were then asked to rate how confident they were of the previous answer, on a scale from 0 (not at all confident) to 4 (extremely confident). Finally, for each door participants were asked to select the colour and material/texture of the door by answering two separate single-choice questions. This allowed the researchers, who did not have control over the viewing screen, to confirm that participants viewed the visual characteristics of the doors correctly.

3.1.3 Participants

Twentyfour participants (15 female) aged 19-65 (14 between 19 and 25, 7 between 26 and 35, 1 between 36 and 50), none of which colourblind, took the online survey. Six of them did not complete the survey, and were therefore not considered in the subsequent analysis of the results.

3.2 Experiment 2

3.2.1 Stimuli

Five images of doors were selected as the most highly associated to the five emotional states considered from those used in Experiment 1 and were used to form audiovisual stimuli for Experiment 2. The selected doors were: red + intermediate wood (RIW) for Anger, yellow + rough wood (YRW) for Fear, blue + metal (BM) for Happiness, grey + smooth wood (GSW) for Neutral, brown + metal (BrwM) for Sadness combinations. Since the results of experiment 1 were not always very clear, we used a number of criteria to select the door-emotion pairs mentioned above:

1. the door must be among those significantly associated with that particular emotion in the results of experiment 1;

2. the door must have a high number of votes (in terms of absolute number of responses) in experiment 1 for the emotion considered;

3. associations between door characteristics and emotion must be confirmed, wherever possible, by previous research. [13, 16, 32] specifically support the red-anger pair, [20, 32] explicitly support the blue-happiness pair, [14, 33] associate yellow to negative valence/unpleasant feelings, and [14, 21] associate grey to negative valence and low arousal.

Finally, the average confidence rate for all five was above 2, which indicates a relatively high degree of reliability in the responses given.

Thirty video clips were produced using Adobe Premiere Pro 2020 by combining the chosen images with six audio recordings of knocking actions. The audio recordings were produced in the context of previous research [10] by a professional Foley artist. The recordings were selected amongst the most highly associated, in our previous study, with the five emotions considered. Additionally we added a second neutral recording. The reason for having two neutral knocking sounds was to be able to investigate whether the lack of a strong emotion in the sound (i.e. neutral) would allow for the emotion evoked by the visual characteristics of the door to affect the overall emotional perception more strongly.

3.2.2 Procedure

As for Experiment 1, an online survey was created in PsyToolkit. In this experiment, after general demographic information, participants were asked whether or not they had participated to Experiment 1. If they answered "yes", their responses were excluded from the results. Participants knowledgeable about sound theory and colour theory were also excluded from results as they were considered to be potentially biased. Before being presented with the stimuli, participants were asked to adjust the volume in their headphones in order to be able to comfortably perceive both the softest and the loudest sounds used for the experiment. For each stimulus, only the evoked emotional state and the confidence were tested as single-choice questions. As before, the order of the stimuli and of the options in each question was randomised.

3.2.3 Participants

One hundred and seven participants took the online survey. Among these, 52 did not complete the survey or had participated to our previous experiment, and 20 had either knowledge about the use of colours in colour theory or about the use of sounds in sound theory, and were therefore not considered in the subsequent analysis of the results. Of the remaining 35, 15 were female, none were colourblind and their ages spanned all available ranges: 3 between 0 and 18, 7 between 19 and 25, 5 between 26 and 35, 3 between 36 and 50, 11 between 51 and 65.

3.3 Experiment 3

3.3.1 Stimuli

A single image of a regular-looking door (brown, with a smooth wooden texture) was rendered in the same way as for Experiment 1 and then animated so to open from 0 (closed) to 100 degrees inwards at three different speeds. The fast version of the animation is 24 frames long, the intermediate version is 48 frames long, the slow version is 96 frames long. 15 video clips combining the door with the three different opening speeds with five knocking actions sounds used in Experiment 2 (one for each emotional state) were produced using Adobe Premiere Pro 2020. To simulate a realistic scenario, the door is closed (represented by a still image) while the knocking is heard and it starts opening (i.e. the door animation starts) at the end of the knocking action (see Figure 2). At a frame rate of 60 fps, the total lengths of the videos varied from three to six seconds.

3.3.2 Procedure

Similarly to the previous two experiments, an online survey was created using PsyToolkit. Participants were asked the same demographics and general information as in the previous experiments, and then to indicate the emotional

Figure 2. Example frame of the door animation used in Experiment 3.

state evoked by the each stimulus together with the degree of confidence in their response. Additionally, for each video clip they were given the opportunity to leave comments or indicate other perceived emotional states in an optional text area.

3.3.3 Participants

Thirty nine subjects started the experiment. Fourteen were excluded due to not fully completing the experiment or due to knowledge in sound theory. Of the remaining 25, 14 were male, 10 female and 1 preferred not to say. Ages were distributed as follows: 1 between 0 and 18, 15 between 19 and 25, 4 between 26 and 35, 4 between 36 and 50, and 1 preferred not to say.

4. RESULTS

4.1 Experiment 1

In all doors colours were recognised correctly, apart from metal white which can be confused with metal grey. The material of the door, metal vs. wood, is recognised correctly. The intermediate wood texture is at times confused with smooth wood or rough wood. As shown in Figure 3, there is a significant relationship between the doors´ colour and the perceived emotions $\chi^2(28, N = 576) = 110.313$, $p < .01$. Looking at pair-wise comparisons with a Bonferroni correction we can see that results are not always clear cut.

For anger there is no significant difference between red, yellow and blue. However red has the highest number of votes, and Red Rough Wood and Red Intermediate Wood have the same number of votes for anger. For fear there is no significant difference between the colours, but yellow has the highest number of votes. And Yellow Rough Wood has the highest number of votes for fear. For happiness there is no significant difference between blue, green, red, white. However blue has the highest number of votes.

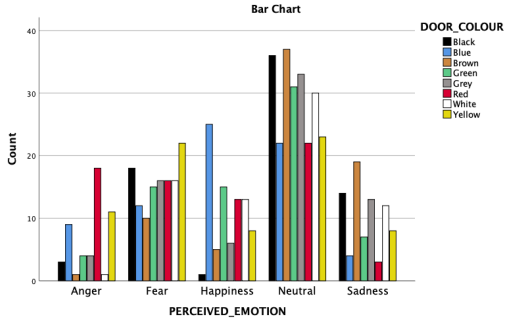

Figure 3. Experiment 1: Door colour vs perceived emotion

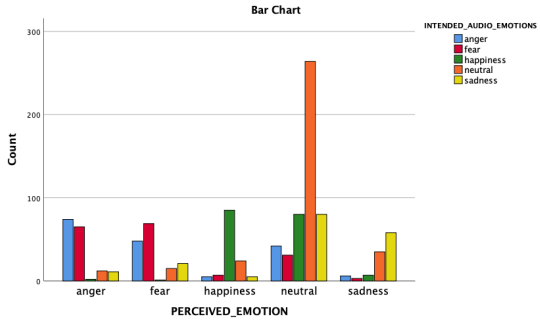

Figure 4. Experiment 2: Perceived emotion vs intended audio emotion

Blue Metal and Blue Intermediate Wood have the same number of votes. For neutral there is no significant difference between all the colours. Brown has the highest number of votes followed by black and then grey. Grey Smooth Wood has the highest number of votes for neutral. For sadness there is no significant difference between brown, black, grey, green, white, yellow. However brown has most votes. Brown Metal has the highest number of votes for sadness. When focusing on emotions and material/texture we find that fear is significantly associated with Rough Wood. While happiness and neutral are significantly not associated with Rough Wood. Overall, by combining these results and information from previous research as mentioned above, we have selected the following door-emotion associations to be utilised in the next experiment: RIW for Anger, YRW for Fear, BM for Happiness, GSW for Neutral, BrwM for Sadness.

4.2 Experiment 2

There is a significant relationship between the intended emotion on the knocking sound actions and the perceived emotion $\chi^2(16, N = 1050) = 803.651$, $p < .01$. There is no statistical significance between anger and fear, but this reflects the results from the previous study [10] from which the knocking actions where selected. Happiness, sadness and neutral are recognised correctly with statistical significance. on the other hand there is no significant relationship between the intended emotion due to the visual characteristics of the door and the perceived emotions $\chi^2(16, N = 1050) = 20.666$, $p > .05$. Overall, the visual characteristics of the door do not contribute to affect the overall emotional perception of these audiovisual stimuli. The sound of the

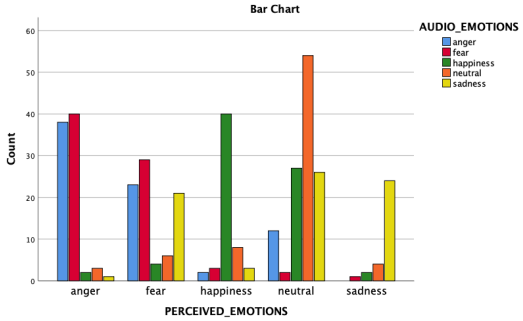

Figure 5. Experiment 3: Perceived emotion vs intended audio emotion: stimuli with sad knocks confused with fear

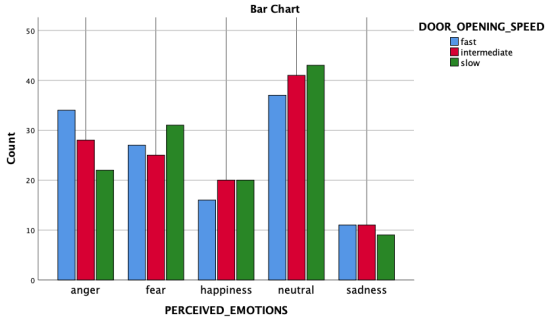

Figure 6. Experiment 3: Perceived emotion vs door opening speed

knocking action is what determines the overall perceived emotion (Figure 4).

4.3 Experiment 3

In this experiment we found that there is a significant relationship between the intended emotion of the knocking sound and the perceived emotion $\chi^2(16, N = 375) = 350.748$, $p < .01$. However, there is an interesting difference with the results of the second experiment: in this case the sequences with knocking sounds that intend to evoke sadness are often confused with portraying and overall emotion of fear (5). From this experiment there is no significant relationship between the speed of door opening and the overall perceived emotion $\chi^2(8, N = 375) = 4.538$, $p > .05$. When looking at sequences associated with anger, the number of votes decreases as the speed slows as we expected, however the results are not statistically significant (6).

5. DISCUSSION

Results from Experiment 1 are consistent with main trends found in previous studies on the association between colours and emotions. More specifically, high-arousal emotions are often matched with warmer colors like red and yellow [19, 20, 22, 23], but also with other highly saturated colours like green and white [14, 19, 32]. Our results also confirm the complexity of the area, as they show that there are no one-to-one associations between a single emotional state and a single colour. However we speculate that a larger sample of people could give a stronger result. An additional reason behind the lack of stronger associations could be the nature of the audiovisual stimuli. In this stimuli two characters are implied: a person who knocks and person who hears the knocks. We leave it to the participant to decide how to interpret the scene as this is what normally happens in the context of media productions. However, it is possible that results could change if participants are told in advance to identify with the person who knocks or the person who hears. Additionally, as displayed in Figure 3, results from Experiment 1 advance the hypothesis that often "Neutral" was used as a go-to option when participants were unsure about their responses to the stimuli presented to them: for all colours except blue and for all materials/textures except rough wood the neutral state was the most frequently selected.

The most important result from Experiment 2 is the larger impact of the aural modality (the recordings of the knocks) on the perception of the overall emotion for the multimodal stimuli presented, compared to the visual modality (the images of doors). It appears that in this case the audio drives the emotional state evoked in the participants, a conclusion which, we speculate, could be due to the different implied sources of the audio and images respectively. While a knocking sound would usually imply the presence of a human as its source who will normally experience emotions, the colour and material of a door are features of an inanimate object, which is not directly tied to emotions. We therefore speculate that, for the participant, the emotion behind an human action, here portrayed by the audio modality, bears more importance than an emotion that is not produced by the door, but is perhaps only the projection of the viewers´ emotion onto the door. We included two neutral knocking actions in this experiment in an attempt to verify whether the colour and material of the door could influence the final perceived emotion more strongly when the audio does not portray a strong emotional state. Results show that the images do not have an increased effect on the overall perceived emotion if the audio is emotionally neutral.

In regard to Experiment 3, we found no significant associations between door opening speed and perceived emotion. When considering the absolute amount of responses for each emotion, we found that stimuli associated to anger were even more frequently associated to it the faster the speed of the door opening. Similarly, stimuli associated to a neutral state were more frequently associated to it the slower door opening (see Figure 6). In other words, these results seem to suggest a relationship of proportionality between the speed of the door opening and the arousal of the emotional state, an hypothesis which could be further explored with a larger number of subjects. Similarly to Experiment 1, the unspecified agency of the opening action (i.e. the fact that the viewer does not know who is opening the door) which was intentional for the purposes of this third experiment, might have contributed to this relatively unclear results. We speculate that if participants knew who is opening the door (the person who knocks or the listener), a clearer emotional state might be evoked as the scene might be interpreted more consistently between

participants. The main and most interesting result from Experiment 3 is that stimuli associated with sad knocking actions now are often associate to fear. A possible reason for this is not only the aforementioned lack of specificity in who is opening the door, but also the negative valence that sadness as an emotion has. The combination of the two elements might create expectation in test subjects that something "negative" is going to happen, which in turn evokes fear in them. From this perspective, participants might to use the two consecutive events (the knocking sound and the opening door) to create an overall interpretation of what is happening and what emotion it evokes. This might suggest that emotions are evoked not only on the basis of what we hear and what we see, but also on the basis of how we explain to ourselves (a kind of storytelling) what might be the most likely origin of the audiovisual stimuli we experience.

6. CONCLUSIONS

With the goal of exploring the perception of emotion in audiovisual representations of everyday sounds, and in particular of knocking sounds, and building on previous research in the field, we have conducted three experiments involving images and animations of doors as well as audio recordings of knocking actions. These enabled us to assess in what measure it is possible to convey emotional cues through combinations of audio and visual features of the stimuli – features like the color, material and texture of the doors represented – and assess the impact that the different modalities have on the perceived emotions. Overall, the results of the three experiments form a strong basis to help us understand how different aspects of an audiovisual artifact contributes to the formation of an overall emotional perception in the audience.

Possible future studies expanding our research could involve several other features of the visual modality – e.g. size of the doors, perspective, distance from the door and field of view – so to compose a more complete picture of how the stimuli presented are associated to certain emotions. Furthermore, similar experiments can be conducted with additional contextual elements, such as scenarios provided to the test subjects or more/different environmental features surrounding the door, and their results compared to those of our study. Alternatively, further possible directions in building on the present research would be based on scaling several of its different aspects: from the medium used (mixed reality, immersive cinematic environments and gaming platforms are but a few alternatives), to the range of emotions considered (possibly based on a different framework like arousal-valence), to the size of the sample population. Finally, conducting the experiment in a controlled environment could enable more control over test variables such as the equipment used and duration of the experiment, as well as more qualitative data to be collected.

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