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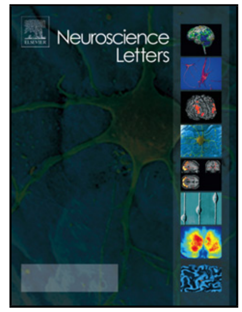

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- Visual familiarity reduces susceptibility to the sound induced flash-illusion
- The effect of familiarity holds for faces and buildings
- Early audio-visual multisensory interactions are modulated by high level processing

Familiarity of objects affects susceptibility to the sound-induced flash illusion

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Abstract

Audition is accepted as more reliable (thus dominant) than vision when temporal discrimination is required by the task. However, it is not known whether the characteristics of the visual stimulus, for example its familiarity to the perceiver, affect auditory dominance. In this study we manipulated familiarity of the visual stimulus in a well-established multisensory phenomenon, i.e. the sound-induced flash illusion. This illusion occurs when, for example, one brief visual stimulus (e.g. a flash) is presented in close temporal proximity with two brief sounds; participants perceive two flashes instead of one. We found that when the visual faces or buildings stimuli were familiar, participants were less susceptible to the illusion than when they were unfamiliar. As the illusion has been ascribed to early cross-sensory interactions between vision and audition, the present work offers behavioural evidence that high level processing of objects' characteristics such as familiarity, affect early temporal multisensory integration. Possible mechanisms underlying the effect of familiarity are discussed.

Familiarity of objects affects susceptibility to the sound-induced flash illusion

Introduction

Visual dominance is a well-established phenomenon occurring when visual processing dominates over other sensory modalities as vision often constitutes the most reliable of the senses [6-8, 10]. For example, in the ventriloquist effect [17] the observer perceives the auditory signal as emanating from the same location as the moving lips that he/she visually perceives. However, visual dominance depends on the characteristics of the task and vision does not always dominate the other senses; as demonstrated by temporal ventriloquism [34] and the sound-induced flash illusion [29].

The sound-induced flash illusion [28-29] is a robust multisensory phenomenon that classically occurs when a single brief visual stimulus (e.g. a flash), is presented with two brief auditory stimuli (e.g. two beeps). In this circumstance participants tend to perceive two visual stimuli instead of one, due to the higher reliability of audition compared to vision in tasks requiring rapid temporal discrimination [1]. The illusion constitutes a robust phenomenological perception [20] that has been ascribed to early cross-sensory interactions [21, 27, 30, 35].

In the present study we aim to assess whether the interaction between audition (which should be dominant in this task) and vision can be altered by higher level features of the stimuli. In particular, we would like to assess whether complex objects (e.g. faces and buildings) are integrated with sound in the context of the sound-induced flash illusion and more precisely whether an object's familiarity can influence early audio-visual interactions. Evidence suggests that audio-visual processing can be modulated by higher level qualitative features of the stimuli [9]. For example, 'synesthetic' congruence (small visual stimulus –

high frequency tone) between a visual and an auditory stimulus alters the perceived temporal window between the stimuli, thus modulating the temporal ventriloquism effect [24]. Semantic properties of stimuli, such as their 'meaning' have been shown to influence multisensory integration very early in the processing stream [22]. Semantic congruency between the picture of a dog and the sound of a dog barking modulated the early visual evoked potential N1 in a study investigating the role of multisensory integration in object recognition [22].

We hypothesize that familiarity affects audio-visual integration. If that is the case, we would expect familiar and unfamiliar objects to be processed differently in the context of the sound-induced flash illusion. The sound-induced flash illusion represents a good way to test the role of visual familiarity in early audio-visual interactions because the illusion originates early in the processing stream [21, 27, 30, 35] and because audition, not vision, dominates in this task [28-29].

Familiarity plays a substantial role in recognition [4]. Familiarity refers to the recognition of a famous or personally familiar person/object (see [19]). This high-level familiarity is related to the whole object (e.g. a pizza) as opposed to its constituent features (e.g. a round shape). Familiar faces are recognised more efficiently than unfamiliar faces [15] and the processing of familiar faces appears to be less affected by changes in viewpoint [19]. Familiarity also helps in recognising familiar faces when the stimuli are impoverished (Mooney faces) an inverse effect occurs for unfamiliar faces [18].

Faces and buildings are processed in different areas in the brain; namely but not exclusively the fusiform face area and parahippocampal place area, respectively [23, 31]. Neuroimaging evidence also shows that familiar faces and buildings, produce activation in the left anterior middle temporal gyrus which has been linked to the processing of semantically unique items, i.e. familiar objects that are associated with specific semantic information in memory (e.g., Elvis Presley's face vs. a generic face) [13].

Considering the advantages in processing familiar visual stimuli compared to unfamiliar ones, it is possible that a familiar stimulus may alter the temporal dominance of audition in the context of early audio-visual interactions, which, in the case of the sound-induced flash illusion, should produce a decrease in the susceptibility to the illusion itself. Alternatively, audio-visual integration in the context of the sound-induced flash illusion may occur too early to be affected by familiarity. Integration of the audio-visual stimuli of the flash illusion appears to occur at early stages of stimulus processing [21, 27, 30, 35] and it is linked to activity in the visual cortex (V1) although it is unclear whether the activity in V1 is due to direct inputs from the primary auditory cortex or to back-projections from the superior temporal polysensory area [35]. As for the time course of familiar stimuli processing, evidence from face recognition studies shows that recognising a face as familiar involves a series of processes [3], including the processing of visual features of familiar individuals, then the unique semantic information associated to the person, and then his/her name (see also [16]). Visual awareness of familiar faces is associated with an event-related potential (ERP) response between 200-300 ms after stimulus onset [12]. Retrieval of bibliographic information of recognised faces occurs around 350/400 ms after stimulus onset, with no familiar-dependent modulation of early ERP (earlier than N200) [cf.5, 25-26]. Therefore, familiarity processing may occur too late to affect the sound-induced visual flash illusion.

Method

Participants

Twenty eight university students (11 male), between the ages of 18-51 years (mean age = 25, St.dev. = 7.3) took part in the study as volunteers. All participants self-reported to have normal or corrected to normal vision and hearing. Participants were Irish or lived in

Ireland for more than one year in order to ensure that they had been previously exposed to the familiar stimuli in this study. This study was approved by the School of Psychology Ethics Committee and conformed to the declaration of Helsinki. All participants provided informed, written consent.

Design and Stimuli

We employed a mixed-design with Familiarity (familiar vs. unfamiliar vs. flash), Visual Repetition (1 vs. 2) and Auditory Repetition (0 vs. 2) as the within-subjects factor and Object Type (face vs. building) as the between-subjects factor. The condition, 1 picture/2 beeps is the condition of interest; while the other conditions (1 visual repetition/1 auditory repetition and 2 visual repetitions/2 auditory repetitions) were introduced as controls to ensure participants were able to perform the task.

Visual stimuli were either a white disk (flash), a face of a famous Irish TV personality (familiar), an unfamiliar face (both male), a photograph of the General Post Office (famous Irish landmark), or a photograph of an unfamiliar building taken from the internet. All visual stimuli had a visual angle of approximately 1.5° and a luminance of 31.54 fl. The visual stimuli were projected 5° below fixation cross against a black background. Each visual stimulus was presented for 12 ms. The auditory stimulus consisted of a brief 3500 Hz beep presented for 10 ms (with 1 ms ramp) at 79 dB(A). Auditory stimuli were delivered through loudspeakers positioned on each side of the monitor at the same height as the fixation cross. The stimulus onset asynchrony (SOA) between the visual and auditory repetitions was 70 ms.

Procedure

Participants were seated in front of the computer monitor (21" CRT DELL Trinitron) with their chin comfortably positioned on a chin rest placed 57cm directly in front of the monitor. At the beginning of each trial, a white fixation cross was presented in the centre of the monitor and remained on display throughout the trial. Participants were instructed to maintain eye gaze on the fixation cross throughout the trial. After 700 ms, the first visual and auditory stimuli were presented simultaneously. The second visual and/or auditory stimulus was presented with a SOA 70 ms. Then, the fixation cross disappeared and participants made a keyboard response to initiate the next trial. The participants' task was to report the number of visual images they saw on the screen, while ignoring the beeps.

The experimental blocks were preceded by a practice block to ensure participants were comfortable with the task. The entire experiment was self-paced. Each condition was repeated 18 times, divided in two blocks (9 repetitions per block). All stimuli were randomized within the blocks. The total number of trials was 216 and lasted approximately 15 minutes.

After the experiment, participants were presented with pictures of the familiar and unfamiliar faces/buildings and were asked if they recognised them. If they answered "yes", then they were asked to state the name of the face/building.

Results

Participants that were not able to recognise the familiar face/building were excluded from the analyses (N = 6; two were presented with faces, and four with buildings). None of the participants recognized the unfamiliar images.

We calculated the proportion of correct trials across conditions for each participant. First, we analysed familiar, unfamiliar and flash separately to ensure that each stimulus produced the illusion when paired with 2 beeps.

A mixed-design ANOVA was conducted on the familiar stimuli only, with Object Type (face vs. building) as the between-participants factor and Visual Repetition (1 vs. 2) and Auditory Repetition (0 vs. 2) as the within participants factors. There was a main effect of Object Type [$F(1,20) = 6.39$, $p < 0.05$]. Participants presented with the buildings responded more accurately (mean = 0.9, St. Err = 0.03) than participants presented with the faces (mean = 0.79, St. Err. = 0.03). There was an interaction between Visual Repetition and Auditory Repetition, [$F(1,20) = 10.5$, $p < 0.01$]. Participants were less accurate in the 1 picture/2 beeps conditions (mean = 0.77, St. Err. = 0.05) compared to other conditions (1 picture/0 beeps = 0.91, St. Err. = 0.03; 2 pictures/0 beeps = 0.81, St. Err. = 0.02; 2 pictures/2 beeps = 0.89, St. Err. = 0.03). Post Hoc Newman-Keuls showed that the difference was significant for 1 picture/2 beeps and 1 picture/0 beeps ($p < 0.05$) as well as 2 pictures/2 beeps ($p < 0.05$) therefore confirming that participants were susceptible to the illusion when familiar stimuli were used.

The same analysis used for familiar stimuli was also conducted for unfamiliar stimuli only. There was a main effect of Auditory Repetition [$F(1,20) = 8.79$, $p < 0.01$], due to greater accuracy in the no-beep condition (mean = 0.87, St. Err. = 0.02) than when pictures were presented with two beeps (mean = 0.81, St. Err. = 0.03). There was an interaction between Visual Repetition and Auditory Repetition [$F(1,20) = 9.11$, $p < 0.01$] with participants responding less accurately when one picture was presented with two beeps (mean = 0.72, St. Err. = 0.05) than in all other conditions (1 picture/0 beeps = 0.87, St. Err. = 0.03; 2 pictures/0 beeeps = 0.87, St. Err. = 0.02; 2 pictures/2 beeps = 0.89, St. Err. = 0.03). Post hoc Newman-Keuls revealed that the condition 1 picture/2 beeps differed significantly from 1 picture/0 beeps, 2 pictures/0 beeps and 2 pictures/2 beeps (all ps < 0.01). The significant difference between the proportion of correct responses to the 1 picture/0 beeps compared to the 1 picture/2 beeps conditions confirms that participants were susceptible to the illusion when the visual stimulus was an unfamiliar object.

A repeated measures ANOVA was conducted on the flash condition, with Visual Repetition (1 vs. 2) and Auditory Repetition (1 vs. 2) as factors. There were main effects of Visual Repetition [$F(1,21) = 5.42$, $p < 0.05$] and Auditory Repetition [$F(1,21) = 12.82$, $p < 0.01$]. Participants responded more accurately to two flashes than to one flash (mean = 0.88, St. Err. = 0.04 and mean = 0.77, St. Err. = 0.02 respectively) and more accurately when there was no beep compared to when beeps were present (mean = 0.87, St. Err. = 0.02 and mean = 0.78, St. Err. = 0.03 respectively). The interaction was also significant [$F(1,21) = 12.86$, $p < 0.01$], as participants were less correct in the 1 flash/2 beeps condition (mean = 0.66, St. Err. = 0.06) than in any other condition (1 flash/0 beeps = 0.87, St. Err. = 0.04; 2 flashes/0 beeps = 0.86, St. Err. = 0.03; 2 flashes/2 beeps = 0.89, St. Err. = 0.02). Post hoc Newman-Keuls revealed that participants were significantly less accurate when presented with 1 flash/2 beeps than when presented with 1 flash/0 beeps, 2 flashes/0 beeps and 2 flashes/2 beeps (all *p*s < 0.01), therefore the illusion was also perceived with the flash as visual stimulus.

In order to compare the susceptibility to the illusions between the familiar, unfamiliar and flash stimuli, we analyzed the proportion of correct responses to the 1 picture/2 beeps condition in a 3x2 mixed ANOVA with Familiarity (familiar vs. unfamiliar vs. flash) as the within-subjects factor and Stimulus Type (face vs. building) as the between-subjects factor. The results showed a main effect of Familiarity, [$F(2,40) = 8.17$, $p = 0.001$]. Separate t tests revealed participants were more accurate (i.e., perceived fewer illusions) when the stimulus was familiar than unfamiliar ($t(1,21) = 2.59$, $p = 0.02$) or neutral ($t(1,21) = 3.55$, $p < 0.01$). Unfamiliar stimuli tended to differ from neutral ones ($t(1,21) = 1.82$, $p = 0.07$). Participants' susceptibility to the illusion was higher for the simple flash and tended to decrease with more complex unfamiliar stimuli, and decreased again for familiar than unfamiliar objects. Figure 1 illustrates the proportion of correct responses for familiar, unfamiliar, and flash visual stimuli when presented with 2 auditory beeps.

Insert Figure 1 about here

Discussion

The present findings represent the first evidence of a qualitative change in audio-visual integration due to higher level characteristics of the stimuli. Not only do we replicate the classical sound-induced flash illusion using simple stimuli but we also show that the illusion occurs with complex stimuli, such as pictures of faces and buildings. Therefore, the illusion is not eliminated by the complexity of the visual stimuli. These results show that qualitative changes in the visual percept due to the presence of auditory stimuli can occur with more naturalistic objects than a flash.

More importantly, the main aim of this study was to assess whether crossmodal auditory dominance was modulated by the familiarity of visual objects. Two alternative hypotheses were contrasted: if familiarity influences the early stages of audio-visual integration, participants should be less susceptible to the illusion when the visual stimulus is familiar. Conversely, if the integration of the visual and auditory inputs occurs independently or at higher-levels of processing, no effect of familiarity should be evident. These results are in agreement with the first hypothesis. Participants were less susceptible to the illusion when the visual stimulus (face or building) was familiar compared to an unfamiliar stimulus.

Therefore, even if audio-visual integration in the sound-induced flash illusion has been ascribed to early perceptual processing, higher-level processes, such as recognising a face or a building as familiar can modulate this early integrative illusion via top-down processing. Previous studies have shown that semantic congruency between the information provided by different senses (e.g., when I see and hear a dog) plays a role in multisensory integration [22, 36]. Our study adds to this literature showing that higher level properties of a visual stimulus alone (i.e. its familiarity), can contribute to determining the resultant multisensory perception. Further studies are needed to establish whether the familiarity of an auditory stimulus may also affect the multisensory percept. Importantly, the effect of familiarity cannot be ascribed to the complexity of the stimuli, as the familiar and unfamiliar stimuli were both complex.

This behavioural experiment does not allow us to disentangle whether the influence of familiarity occurs during early processing in primary visual areas, at later polysensory processing stages, or the illusion may occur at early processing stages but higher level features block this low-level interaction from being expressed as an illusion. It has been shown that awareness of familiarity is associated with an ERP occurring 200-300 ms after stimulus onset [12], however the recognition process starts early and it may interact with audio-visual integration before awareness. Object recognition studies demonstrate that subliminal recognition of a familiar object can influence subsequent perception [e.g. 32, 33]. This suggests that an early interaction between top-down and bottom-up processing is possible. Alternatively, it is possible that the effect of familiarity occurs at the response level. In the illusory condition (e.g., 2 beeps/1 flash) participants may respond more conservatively, deciding that when they see a familiar visual stimulus it is more likely to be repeated once than twice. However, participants were also exposed to 2 real familiar stimuli (e.g. in the 2 familiar faces/2 beeps condition) therefore the response '1' is not always correct. In addition, all the stimuli were randomised within blocks to avoid response strategies. Even if this study does not allow us to exclude the possibility that familiarity occurs at response level, it should be noted that the sound-induced flash illusion is considered a perceptual phenomenon; therefore it is unlikely to be affected by response strategies. ERP studies investigating the illusion with complex familiar and unfamiliar stimuli would clarify this issue.

Furthermore, the exact mechanism allowing familiarity to affect this illusion remains to be established. One possibility is that familiarity enhances visual processing of the familiar stimulus [15], thus reducing the influence that an auditory stimulus has on the multisensory percept. Bhattacharya et al. [2] compared γ-band response activity in visual cortical regions for trials in which participants perceived the sound-induced flash illusion or not and suggested that the "perception of illusory double flash is only possible when the modulated visual activity by sound exceeds a 'perception threshold' for being registered as a flash percept, otherwise the modulation is unable to trigger awareness" (p.1729). It has been shown that memory retrieval of known stimuli (i.e., previously learnt) also affects γ-band responses compared to unrecognised objects [14]. The time frame for γ-band differences between illusory vs. non-illusory trials [2] and the retrieval of recognised stimuli [14] is similar. Therefore, familiarity may affect the perceptual threshold for the illusory visual stimulus to be perceived.

The attentional set may also change when different kinds of stimuli, other than just the flash are used. As a consequence familiar objects in this task may be locally as opposed to globally processed [11]. In this case the temporal interactions between beeps and visual stimuli may be altered.

Further studies will disentangle the multisensory processing of familiar and unfamiliar stimuli in the context of early audio-visual interactions; EEG will be of particular interest in this context.

Conclusions

For the first time, we demonstrated the susceptibility of the sound-induced flash illusion by using simple (flashes) and complex visual stimuli (buildings and faces). More importantly, familiar visual stimuli diminished the susceptibility to the illusion compared to unfamiliar stimuli. We argue that familiar visual stimuli reduce auditory dominance in this task, thus generating fewer illusions. Further work will be needed to elucidate the mechanism underlying the effect of familiarity reported here and to assess whether a familiar auditory stimulus also alters the susceptibility to the illusion compared to an unfamiliar sound.

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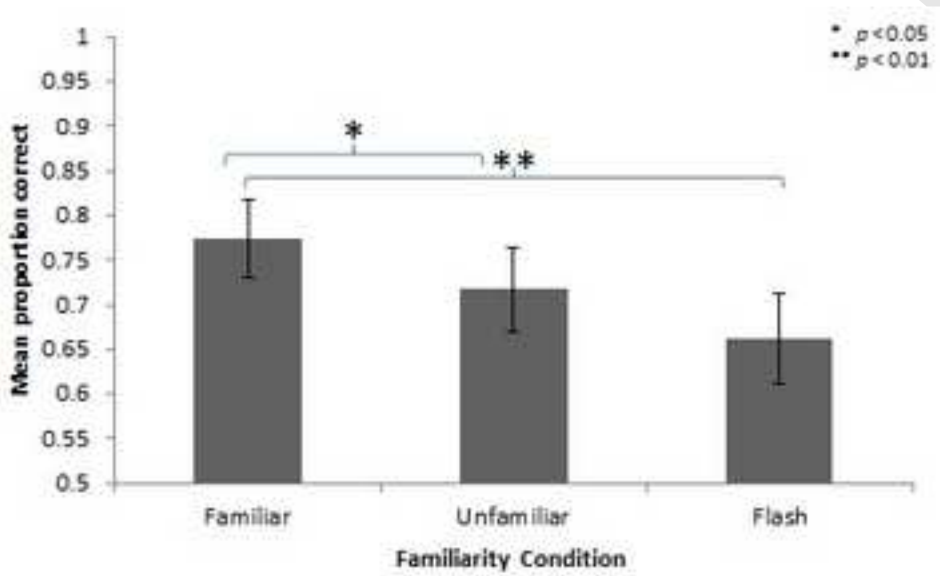
Figure 1. Proportion of correct responses when the stimulus was familiar, unfamiliar or a flash in the 1 picture/2 beeps condition. Significant effects are marked by asterisks. Error bars represent 1 standard error of the mean.

Figure


* p < 0.05
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Mean proportion correct
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Familiar
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Familiarity Condition