Dissociable Effects of Faces on Attention During Constrained and Unconstrained Viewing

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Short title: Context Effects in Attentional Capture

Abstract (160 words)

It has long been proposed that some stimulus classes are so biologically important that they are automatically prioritized by the attention system, irrespective of context. However, issues of ecological validity undermine laboratory-based experiments that attempt to establish the existence of context-independent attentional biases. Here we measured attention to faces and facial expressions of emotion while participants were sitting in a waiting room before the experiment, and again in the same individuals in a laboratory-based reaction-time (RT) task. A robust bias towards images of faces was observed in the waiting room, but not in the RT task. Conversely, a robust attentional bias towards emotional faces was observed in the RT task, but not in the waiting room. Despite large individual differences in attentional biases towards face and facial emotions, measures of bias in a given individual in one setting did not predict their bias in another. We conclude that attentional capture by faces and facial emotions is highly sensitive to context.

Keywords: attention, eye movements, ecological validity, face perception, individual differences

Our senses take in far more information than we can possibly process. Efficient, goal-directed behaviour therefore depends critically on the selection of relevant or important information, together with the successful filtering and suppression of irrelevant information. This is the main function of selective attention. As important as it is to select relevant information, however, it is also important that attention not become so focused on this information that events that are unexpected, but nonetheless important, escape our notice. This need to balance top-down control of attention with a mechanism through which unexpected events can still be noticed has led to the proposal that there are two subsystems of attention: one “top-down” system which selects information that is part of our current attentional set, and relevant to our task or context, and one “bottom-up” or stimulus-driven system which alerts us to the presence of important but unexpected information. This conceptual division has been around since at least William James (1) and has developed into a useful model of attention associated with distinct brain networks (2, 3).

The concept of bottom-up attention has led to the important question of what are the categories or characteristics of stimuli that have the capacity to capture our attention in an involuntary manner, that is, in a manner that is insensitive to the ongoing task or context of the individual. The list of possible stimulus classes includes low-level visual features like local transients (4), and luminance increments or changes (5), as well as high-level object categories, like faces (6, 7), facial expressions of emotion (8, 9), and fear-inducing stimuli like snakes and spiders (10). Faster responses to these classes of stimuli (11), and slower responses to other classes of stimuli when these are present (12), has led researchers to argue that they capture attention in an involuntary, context-independent manner (13, 14). That the effects of these classes of stimuli on attention are strictly context-independent has proven difficult to demonstrate, however. Distractors that have been characterized as “irrelevant” can share subtle features with the target, leading to interference or capture that is in fact a reflection of top-down attentional control (15, 16). Many seemingly context-independent effects, particularly for higher-level object categories, have also been shown to depend

on image-level details, task instructions, and individual differences (e.g. 17,18). Inconsistent findings and a dependence on task-set could be evidence that the orienting bias in question is not automatic or context-independent, but is in fact an example of top-down attention.

More generally, issues of ecological validity are particularly important when trying to answer the question of which “default” classes of stimuli may be able to capture attention in a bottom-up way. Most studies measure participants’ ability (through eye movements, manual reaction time, and/or accuracy) to repeatedly perform a particular task under controlled conditions in the presence of “irrelevant” distractors. If such an experiment fails to produce evidence for attentional capture by a particular class of stimuli, it is possible to argue that the artificial, repetitive nature of these laboratory tasks has masked effects that would be robust in more natural, realistic situations. Following this argument, attentional biases should be *more* robust if they could be measured under less constrained viewing conditions. The problem with testing this assumption is that less behavioural constraint means more behavioural noise, so it can be difficult to detect a subtle but systematic bias in attention under “natural” conditions.

On the other hand, if a laboratory-based experiment succeeds in finding evidence for attentional capture, it is possible to argue that the artificial, repetitive nature of these laboratory tasks has caused participants to adopt an attentional control setting (15) or task-related strategy that distorted the way they prioritized information. Such distortions could lead to over-generalizations and erroneous conclusions based on results that depend critically on some artificial component of the laboratory environment. Following this argument, attentional biases observed in a laboratory setting may be *weakened* if the task and context could be made more natural and unconstrained. It is difficult to test this assumption as well, because it requires comparison of results across environments in which “targets” and “distractors” can have very different low-level properties. That said, recent experiments have attempted to bridge the gap, to test the extent to which behavioural patterns in laboratory settings can be detected in more realistic and unconstrained environments.

For example, Petersen, Lin, Zaun & Kanwisher (19) measured the bias in fixations on particular facial features and found similar biases in viewing faces on computer screens in a laboratory as compared to viewing real faces as participants walked around campus; for example, participants who tended to fixate mouths rather than eyes in the laboratory also did so in the real world.

Here we attempted to directly test whether context influences attentional biases towards faces and facial expressions of emotion relative to a control category of stimuli (trucks). We measured the attentional biases within the same set of individuals both a typical reaction-time experiment and in the waiting room before the experiment began. We reasoned that as long as we had sufficient power to detect stable attentional biases towards a particular class of stimuli in both contexts, those biases should be similar in type across contexts if they are indeed reflexive and not affected by context. It has been shown previously that individual differences modulate the extent to which stimuli can capture attention (for example, there are stronger effects of social and emotional stimuli amongst people with anxiety, e.g., 6, 13). Thus we assumed there would be variation in the extent to which individual participants are biased towards particular classes of stimuli. Individuals that do show a strong bias towards one stimulus category should do so across both settings if these reflect stable traits in how these participants filter and process information in the world around them. Conversely, to the extent that context drives attentional capture effects, we will see variability across settings both in terms of the type of stimuli that attract attention at the group level, as well as in the attentional biases exhibited by a given individual.

Materials and Methods

Overview. Upon arrival in the laboratory, each participant was fitted with a pair of SMI eye-tracking glasses and told they were taking part in a study on reactions to users of wearable technology. The experimenter showed the participant an orange, telling them they would have to walk to the main office of the building to retrieve it from a mail slot and then return to the lab while wearing the glasses. The experimenter left to place the orange, leaving the participant alone in the room for

around two minutes. Inside the room, two computer monitors displayed a series of images from two categories. In the first experiment the two categories were faces and trucks, and in the second experiment they were faces with fearful and neutral expressions. After the participant returned with the orange, they completed a reaction time (RT) task, pressing a key to localize different images from the same two categories displayed in the waiting room. This method allowed us to measure the robustness of any bias towards a particular stimulus class within each task context, as well as the stability of the bias in a particular individual across two contexts.

Participants. For Experiment 1, 22 participants were recruited. Two were excluded because they failed to keep steady fixation during the RT task. Of the remaining 20, 10 were male, with a mean age of 24. For Experiment 2, 24 participants, none of whom participated in Experiment 1, were recruited. Four were excluded for poor calibration and eye tracking quality. Of the remaining 20, 10 were male, with a mean age of 22. All participants had normal vision or corrective contact lenses and were students at the University of Aberdeen. The experiments were approved by the Aberdeen School of Psychology's ethical review board, which follows the British Psychological Society Code of Human Research Ethics and the principles of the Declaration of Helsinki. The experiment adhered to the approved protocol and all participants gave informed consent to participate. When asked after the experiment, none of the included participants were aware that their eye movements were recorded.

Equipment and stimuli. A pair of SMI Eye Tracking Glasses™ was used to record gaze position. The equipment allowed binocular recording at a sampling rate of 60Hz, capable of estimating the gaze with $<0.5^\circ$ accuracy. Face stimuli consisted of 104 identities chosen from the FACES database (20) with neutral (Experiment 1) and both neutral and fearful (Experiment 2) facial expressions. Half of the faces were young and half from the older age category, and half the faces were female. Photographs of trucks, viewed from directly in front, were used as control images in Experiment 1 because their configuration is similar: the headlights may resemble the eyes of a face (21), and

trucks were chosen over cars because they are more portrait-like in their orientation. All pictures were formatted to greyscale and the background luminance of all images was matched. Half of the images (52 pictures from each respective category) were used in the waiting room context, and the other half used in the RT task. For this, a programme was created in E-Prime 2.0 that presented randomised successions of images on two separate computer monitors, with a single image category exclusive to a single screen. The screen resolution of both monitors was 1280 X 1024 pixels and set at a distance of three metres from participants. The remaining half of the stimuli were sized to 6.9° by 6.9° and paired together for use in the manual-response localisation task. Two stimuli were presented to the left and right of a central fixation cross, centred at 6.9° eccentricity at a viewing distance of 57 centimetres. Stimulus pairings were based on luminance: face and truck images with comparable luminance (± 2 cd/m²; mean face luminance: 26.43 cd/m², mean truck luminance: 25.11 cd/m²) were paired together to reduce the likelihood of attentional capture based solely on luminance properties. The mirror image of each pairing was also generated to create balanced stimuli; thus, each pairing was shown twice. Stimulus pairings were presented to participants centrally on a 21" CRT monitor (600 X 800 pixels) with a refresh rate of 100Hz using an SVGA graphics card (Cambridge Research Systems, UK). Each pair of stimuli was presented for 500ms.

Procedure. Participants were told that the goal of the study was to measure people's responses to wearable technology, such as google glass. To maintain this deception, participants were asked to walk to the main office of the building to retrieve an orange from a mail slot and bring it back to the laboratory while wearing the SMI mobile eye-tracking glasses. They were fitted with the glasses while seated at a table in the entry room to a laboratory suite. The room contained two computer workstations at one end (see Figure 1), which were on with open applications. After a one-point calibration procedure, the experimenter left the room, stating they were placing the orange for the participant to retrieve. The participant was left alone in the room for approximately two minutes. Following a short delay, first one and then the other display began showing images of faces or trucks at a rate of 2Hz. The total duration of the image stream was 60-65s. In the first experiment, one

display showed young and old faces with neutral expressions and the other showed trucks. In the second experiment, one display showed neutral face and the other showed fearful faces. The orders in which the stimuli began and the assignment of stimulus class to display were counterbalanced across participants. Participants then walked to the main office to retrieve the orange from the mail slot (this was just a filler task; eye movement data were recorded but are not reported here). Upon returning, participants were seated at a computer and asked to indicate, by pressing one of the two response buttons, the location of the neutral face, for four blocks of 26 trials. In an additional four blocks of 26 trials, the task was to indicate the location of the truck (Experiment 1) or the fearful face (Experiment 2). The order of the tasks was counterbalanced across participants. Participants also completed the state-trait anxiety index (STAI) at the end of the experiment.

----Insert Figure 1 here---

Figure 1. Methods. **(a)** Example stimulus pairs in Experiment 1 (top) and Experiment 2 (bottom). **(b).** View from participants' seat in the "waiting room". Participants were left alone in the room for 2 minutes and the screens displayed a series of images for 500ms each. **(c).** Trial sequence in the reaction time task.

Analysis. SMI BeGaze™ analysis software was used to identify the number and duration of fixations on, or within 1° of, the two screens on which the stimuli were presented. Eye movement recordings during the RT task were used to ensure that participants maintained fixation on the central cross throughout the trials. Because the proportions of fixation time spent on the two AOIs are non-independent, paired t-tests are not appropriate for comparing the number of fixations or total dwell time; instead, the "dominance ratio" was tested against 0 in a one-group t-test. For Experiment 1, this ratio was the total time spent looking at the face, minus the total time spent looking at the truck, divided by the total duration of the time in the waiting room. Experiment 2 used the same ratio (fearful minus neutral, divided by the total). In the RT task, median RT for each participant to correctly locate the target was calculated for faces and trucks (Experiment 1) and neutral and fearful faces (Experiment 2). Paired samples t-tests were used to compare conditions. A summary of mean duration, number of fixations, and total fixation duration in the waiting room are presented in Table

1; all three follow the same pattern so total fixation was chosen to be analysed as it incorporates the other two measures. The “Other” category in the table below comprises fixations falling anywhere else in the room besides the two regions of interest.

Results

Results are displayed in Table 1 and Figure 2. In Experiment 1, participants exhibited a clear bias towards faces over trucks in the waiting room (Figure 2a), fixating them for a significantly larger proportion of the two-minute duration ($t(19)=3.36$, $p=.003$). In the laboratory setting, however, there was no difference in either RT ($t(19)=-0.92$) or accuracy ($t(19)=0.78$) to respond to these two stimulus classes. For Experiment 2, pairing fearful and neutral faces, the opposite pattern emerged: there was a robust advantage for emotional faces over neutral faces in the laboratory setting in both RT ($t(19)=5.35$, $p<.001$) and accuracy ($t(19)=3.48$, $p<.001$), but no tendency to look more at emotional faces compared to neutral faces in the waiting room ($t(19)=0.78$, Figure 2b). To ensure we had sufficient power to detect correlations in this dataset, we correlated RT and accuracy biases (two measures from the laboratory session of each experiment) and found a significant positive relationship ($r=.427$, $p=.006$). We likewise correlated two measures from the waiting room: the dominance ratio calculated from the total fixation duration and the dominance ratio calculated from the number of fixations. Again, we found a significant positive relationship ($r=.861$, $p<.001$). No correlations *between* experimental settings reached significance, however (Figure 2c), suggesting that participants who show a strong or weak bias towards a particular class of stimuli in one setting do not demonstrate a similar bias towards that class in another setting.

---- Insert Figure 2 here ----

Figure 2. Fixation duration, reaction time, and accuracy from the two experiments. Error bars represent the 95% confidence interval around the difference between stimulus classes. Asterisks indicate significant contrasts. **(a)** Experiment 1 results, pairing face and truck stimuli. **(b)** Experiment 2 results, pairing fearful and neutral faces. **(c)** Across both experiments, bias in the lab task does not correlate with bias towards the same stimulus in the waiting room.

We also examined the role of state and trait anxiety in our effects as previous work has reported a link (6, 13). State and Trait anxiety were significantly correlated with each other ($r=.442$, $p=.004$). The RT bias correlated significantly with state anxiety ($r=.326$, $p=.040$) and marginally with trait anxiety ($r=.292$, $p=.067$). The dominance ratio for total fixation duration did not correlate with either anxiety measure.

Table 1: Summary of the waiting room eye movement data.

Experiment 1	Number of Fixations	Mean Fixation Duration (ms)	Total Fixation Duration (s)
Neutral Face	72.85	464.16	33.04
Truck	51.05	388.96	17.67
Other	54.20	252.61	14.14
Experiment 2	Number of Fixations	Mean Fixation Duration (ms)	Total Fixation Duration (s)
Fearful Face	66.05	385.49	25.36
Neutral Face	62.95	374.65	21.89
Other	60.00	237.19	15.64

Discussion

The results produced a clear double-dissociation in attentional bias between the two contexts. In Experiment 1, the laboratory-based reaction time task failed to produce a measurable bias towards faces over trucks. However, the same group of participants showed a clear bias towards faces as measured through their fixation behaviour in the waiting room. This result is consistent with the interpretation that robust attentional biases towards faces can be weakened or eliminated when experimenters try to study them using a repetitive and artificial laboratory task. Trucks and faces differ in low-level visual features, making rapid categorization possible through basic form matching. The minimal processing required to make a response may have masked attentional biases towards faces under repeated exposure in the RT task. In the “real” world, however, that same distinctiveness allows attention to be guided to, and remain fixed on, the more intrinsically interesting object, suggesting people do have a clear bias towards faces under normal

circumstances, consistent with previous studies demonstrating an intrinsic bias towards faces over other stimuli (e.g. 7, 12). An important conclusion we can draw from our results is that a face bias can be strongly attenuated or eliminated when the visual processing requirements for the task being used to measure that bias are relatively minimal, which is often the case in laboratory tasks. Our results reinforce the idea that the kind of stimuli that attract attention depend critically on the features that can be used to identify the target relative to distractors (15).

In Experiment 2, the reaction time task produced results consistent with an attentional bias towards emotional faces, with significantly faster RT to localize emotional over neutral faces. This replicates a well-known effect in the literature (e.g. 11). Importantly, however, we find no evidence of this bias during unconstrained viewing. The effect of emotional faces in the laboratory task may be an artefact of the way in which the task itself is framed: we asked participants to respond to the fearful or the neutral expression, and the fearful expression may be framed as the existence of a feature while the neutral expression may be framed as the absence of that same feature. This may make detection of the fearful expression faster than detection of a neutral expression. Our interpretation of the current results is therefore that the specific constraints of the laboratory task biased participants to respond more quickly to the emotional face, but when these constraints were not present (i.e. in the waiting room), no bias towards these stimuli was observed. Although some studies have observed a bias towards negative emotional expressions (8, 9) our results are consistent with several studies failing to find evidence for automatic negative biases in non-clinical populations (e.g. 17, 18).

An alternative explanation for the difference in results across the laboratory and waiting room contexts could be that the type of dependent variable measured (fixation behaviour versus manual responses) results in different patterns of bias. Indeed, previous research has suggested response modality is an important factor mediating the effect of emotion on attention (11). However, that research demonstrated that eye movement responses in a constrained RT task exhibit larger and

more robust effects of emotion than manual responses, and so cannot explain the current findings, which replicate effects of emotion on manual responses, but demonstrate these are not observed in the unconstrained eye movements of the same observers. More generally, the two experiments taken together provide solid evidence that both contexts are capable of producing measurable effects: in Experiment 1, robust effects of stimulus class emerged in the waiting room context, and in Experiment 2, robust effects of stimulus class emerged from the laboratory context. Thus it is not that one context produces no measurable effects on attention, rather, the attentional biases that dominate in each context are distinct.

The assumption that mental processes, such as those driving attention, scale from simplified contexts to more complex and unconstrained ones stems from a basic assumption of experimental psychology that has its roots in the cognitive revolution of the 1950's and has been the foundation for the vast majority of behavioural research conducted since then. This assumption has been questioned both historically (22) and recently (23), but the vast majority of research is still guided by this viewpoint. We have shown here that a laboratory phenomenon previously assumed to result from context-independent orienting of attention fails to emerge during unconstrained viewing, and a clear bias in unconstrained viewing was not observed in the laboratory. Our results imply caution when interpreting attentional capture results and suggest a way forward for examining the ecological validity of this and other laboratory-based findings. Other classes of stimuli previously suggested to capture attention in a context-independent manner may produce stable results across both settings. These remain to be explored.

Acknowledgments. We thank James Urquhart for technical support.

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Notes

Data Accessibility. The data from these two experiments have been uploaded to the Open Science Framework [<https://osf.io/5ujcx/>].

Competing interests. The authors have no competing interests.

Funding. This research was made possible by a James S McDonnell Scholar Award (ARH), support from the Alexander Pigott Wernher Memorial trust (AS), and a Carnegie-Cameron postgraduate Bursary (KR).

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