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Changes in alpha activity reveal that social opinion modulates attention allocation during face processing

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A R T I C L E I N F O

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A B S T R A C T

Participants' performance differs when conducting a task in the presence of a secondary individual, moreover the opinion the participant has of this individual also plays a role. Using EEG, we investigated how previous interactions with, and evaluations of, an avatar in virtual reality subsequently influenced attentional allocation to the face of that avatar. We focused on changes in the alpha activity as an index of attentional allocation. We found that the onset of an avatar's face whom the participant had developed a rapport with induced greater alpha suppression. This suggests greater attentional resources are allocated to the interacted-with avatars. The evaluative ratings of the avatar induced a U-shaped change in alpha suppression, such that participants paid most attention when the avatar was rated as average. These results suggest that attentional allocation is an important element of how behaviour is altered in the presence of a secondary individual and is modulated by our opinion of that individual.

Introduction

A commonly observed phenomenon in psychological research is that an individual's behaviour in a task is altered when conducted in the presence of another individual compared to when the task is done alone (Ringelmann, 1913). This effect is seen in a wide range of behaviours, for example participants eat more in the presence of someone else who is eating (Herman, 2015), participants' performance in cognitive tasks decreases for complex tasks in the presence of a secondary individual (Bond and Titus, 1983), and these changes occur even when interacting with human-like computers instead of actual secondary persons (Mandell et al., 2015). Although the effect of the presence of a secondary individual is not consistently positive or negative, there have been many behavioural studies establishing this phenomenon in different contexts. However, few have also investigated the mechanisms underlying the behaviour seen. Our study will be a step towards understanding how this process is implemented neurally.

In addition to the mere presence of a secondary individual, the opinion the participant has of this individual also influences the participants' subsequent behaviour (Heyselaar et al., 2017; Lott and Lott, 1961; Weatherholtz et al., 2014). One possible explanation for the phenomena discussed thus far involves the capture of attention by the secondary individual. Specifically, conducting a task in the presence of another person could cause one to divide their attention between the individual and the task, compared to when the task is done alone (for a review see Strauss, 2002). Additionally, if one finds the secondary individual more likeable, this could influence how much (or how little) attention is allocated to the secondary individual.

One way to investigate the neural processes related to attention is through electroencephalography (EEG), a non-invasive neuroimaging technique that measures the electrical potential generated by neurons. The EEG signal contains oscillatory activity in distinct frequency bands that have been found to map on to different facets of cognition (Siegel et al., 2012). Alpha activity, an oscillation occurring at a frequency of 10 Hz, has been suggested to play a pivotal role in attention (Foxe et al., 1998; Mazaheri and Jensen, 2010). According to this framework, the suppression of alpha activity relates to the degree of cortical activation whereas an increase in alpha activity relates to cortical inhibition. It is proposed that alpha activity is mostly driven by forward propagating dendritic currents, and modulated (i.e. inhibited) by GABAergic feedback from interneurons (see for review Mazaheri and Jensen, 2010). While the precise mechanism in which alpha activity exerts functional inhibition is

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not fully understood, some recent work suggests that alpha oscillations exercise a strong inhibitory influence on both spike timing and firing rate of neural activity (Haegens et al., 2011; Mazaheri and Jensen, 2010). Recently, a more nuanced view of alpha activity has been proposed in which its modulation of power is not strictly reflecting inhibition of sensory input (Van Diepen and Mazaheri, 2017). Rather, here the absolute baseline level of alpha power in a sensory cortex reflects the *default* allocation of neural resources earmarked to that region for processing. Any changes in alpha power in that region due to task demands reflect not necessarily inhibition but the redistribution of resources to optimise task performance. For this study we specifically focus on alpha activity as a representation of attentional allocation towards the secondary individual and modulations in the degree of alpha power/attention as a function of the opinion participants have of this secondary individual.

For this study, participants interacted with and subsequently evaluated digital secondary individuals (hereafter “avatars”). We measured the EEG activity during the viewing of the face of the avatars prior to their interaction and evaluation in Virtual Reality as well as after. As a control we also presented the face of avatars participants did not interact with. This design insures that the visual stimulus (in this case the face of the avatars) is constant, allowing us to investigate modulations of neural activity brought about by the interaction with, and evaluation of, the avatars.

In sum, the first aim of our study is to determine whether viewing an avatar the participant has interacted with results in a different degree of attentional allocation (as indexed by changes in alpha activity) compared to viewing an avatar the participant has not interacted with. We will therefore provide neuroimaging evidence which may clarify why participant behaviour is different when conducting a task in the presence of a secondary individual. Our study is one of the first, to our knowledge, to provide evidence for what has thus far only been theorised. The second aim is to determine whether the amount of attention allocated (measured as modulations of the change in alpha activity post-versus pre-interaction) to the avatar varies as a function of the participants' opinion of that avatar, something that again has not been tested before. Thus here we endeavour to be one of the first to provide a neurobiological explanation for behaviour seen in social psychology and social psycholinguistics.

Methods

Subjects

30 native Dutch speakers (2 male, M_{Age}: 21.53 years, SD_{Age}: 2.60) gave written informed consent prior to the experiment and were monetarily compensated for their participation. As the EEG cap had to fit underneath the virtual reality (VR) helmet, we were limited to testing participants with small head sizes (58 cm diameter and below), restricting us to mostly female participants. It is possible that there are gender differences in the influence of social opinion on task performance but our data do not allow us to investigate this further.

Procedure

The participants were informed that there were three phases to the experiment, but at the beginning of the experiment, they only received detailed information about Phase 1. At the start of Phase 2 they were informed of the goal of the study. The entire procedure is summarized in Fig. 1.

Participants initially viewed 565 static photos, of which 400 were of the 4 avatars. The faces of the four avatars were all exactly the same, and hence to be able to discriminate between photos of them, they were given different shirt colours. For Phase 2, participants interacted with three of the four avatars in Virtual Reality. Here the avatars were animated such that each avatar had different facial expressions in terms of their smile habit, eyebrow movements, and blink rate (see Table 1). The animations of the facial expressions were consistent for the entirety of the virtual interaction. Participants were therefore able to form opinions about the three avatars based on these facial characteristics, an effect seen robustly in previous studies using the same avatars and same facial expressions (Heyselaar et al., 2017). After each interaction, participants were asked to evaluate the avatars. For Phase 3, the participants were again shown static pictures. The participant used the colour of the shirt to discriminate

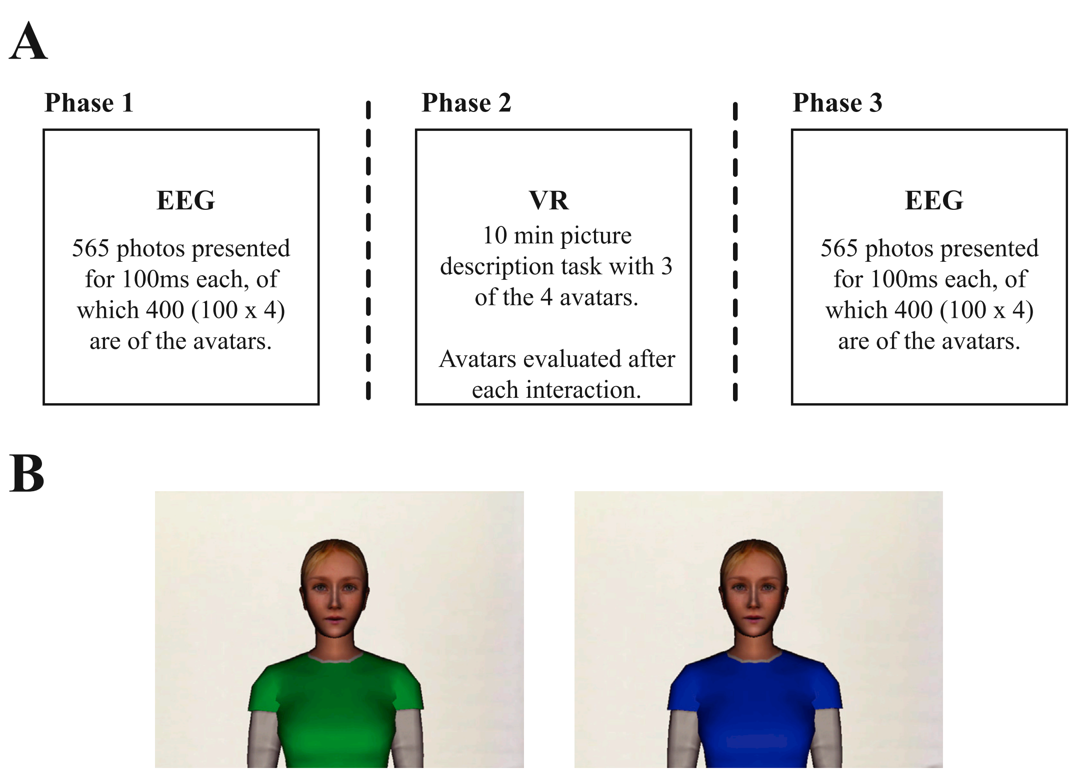

Fig. 1. A. Procedure **B.** Examples of two of the four avatars. Avatars were presented with green, blue, red, and yellow shirts.