Detecting Familiarity of Faces Through Pupillometry and RSVP

Konstantinos Mazarakis

s3709078

Department of Psychology, University of Groningen

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Supervisor: Dr. R. van der Mijn

Second Evaluator: Assistant Professor Dr. P.H. de Vries

In collaboration with: A. de Jong, L. Masara, N. Van Waveren Hogervorst and R. Wagenaar

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Abstract

EEG and pupil size have been used to detect if someone is familiar with a stimulus without actively searching for it. In studies with the use of EEG and RSVP (Bowman et al., 2013) it was shown that the brain pattern observed while seeing a stimulus that someone actively searches for is similar to the one when someone is familiar with a stimulus but not actively searching for it. While EEG is effective, it is considered to be expensive and there are not a lot of places that have one. Here we show that the combination of pupillometry and RSVP can be a promising alternative to the EEG in order to detect hidden information. In our study, we found that the pupil size while seeing a familiar face (probe) without paying attention to it, only slightly differs from the pupil size observed while seeing a random face. The small visual difference that was observed was not found to be significant. The results contradict our main hypothesis and the results from previous studies and it supports the need for further investigation. Our results support that pupillometry as an alternative to the use of EEG is not as accurate and thus cannot replace it. We anticipate that our study will elicit further interest in investigating how pupillometry can have similar accuracy as the EEG in detecting subliminal information. Modifications in future studies could find more promising results in familiar stimulus detection. Moreover, a significant finding in this related topic could be crucial in criminal justice and in the forensic field.

Keywords: RSVP; Subliminal salience; Pupillometry; Faces

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Introduction

The need to find a way to uncover if someone is lying or trying to deceive someone goes back to approximately 1000 B.C. in China and 300-250 B.C. in Greece (Vicianova, 2015). Nowadays, the consequences of not being able to detect when someone is lying are evident especially in criminal justice where it has been found that from 1989 to 2017 more than 2100 people were wrongly convicted in the USA and were later released after founding evidence of their innocence (Johnson, 2020). Some of the reasons that could be contributed to these false convictions are false confessions and mistaken eyewitnesses (Kassin, 2005; Linsday & Wells, 1985). Hence, it is important to measure such knowledge objectively.

Sometimes individuals can hide the information intentionally, even if it is present in their long-term memory, for example, an individual can lie to avoid jail time. It was found that some physiological changes can "give away" when someone is lying. Changes in respiratory, blood pressure and pulse rate (Grubin & Madsen, 2005) were found to be indicators that someone is lying. The first and most complete attempt to measure these changes effectively was the creation of the polygraph in 1921 (Synnot et al., 2015). The polygraph was used worldwide in many cases, especially in criminal justice (Grubin & Madsen, 2005), however, nowadays its use is mostly complementary since a lot of countermeasures have been found (Handler et al., 2015). In the last decades, the attention shifted to the familiarity of a stimulus and the physiological changes that are caused when seeing a stimulus characterized like this.

According to the mere-exposure effect, people tend to develop a stronger familiarity with a stimulus when they are repeatedly exposed to it, and subsequently show a preference for it (Zajonc, 1968; Yagi, 2018). Frequent exposure to a stimulus makes this stimulus more familiar to the observer, leading to faster recognition (Ramon et al., 2011) but also faster

processing speed (Manahova et al., 2020). Hence, to recognize a face, it should be familiar to us and for that to happen it should be saved in our memory, such as the short-term memory and the long-term memory.

The short-term memory model (STM) by Kolb and Wishaw (2009) suggests that information is transferred from our sensory systems such as sight and smell to our cognitive systems. The capacity of the short-term memory is limited and is estimated to be 7 +/- 2 items (Miller, 1956). This means that the information can only stay in our short-term memory for about seven seconds, after which it is either lost or processed into our long-term memory. On the other hand, working memory (WM) has to do mainly with the controlled manipulation of a limited amount of information (Postle, 2016). If an item or a face is familiar to us we have a visual representation of it in our visual working memory (VWM) which is easier to get access to but also easier for it to draw our attention unconsciously (Gayet et al., 2013). This concept is also known as priming, which is a method of influencing how people respond to a future stimulus by introducing one stimulus first. Priming activates a memory association or representation immediately before another stimulus or activity is presented (Elgendi et al., 2018)

The information saved in our long-term memory can be recalled whenever needed or suppressed if it is not required to be recalled immediately. Stimuli that have been presented to someone multiple times like an item or a face have a strong chance to get saved in the long-term memory and become more familiar to him thus making it salient (Zhan et al., 2018). When an item is considered to be salient it means that even though we may not consciously process it, subconsciously it attracts our attention, break through into consciousness and is processed faster and more easily than an unfamiliar stimulus (Bowman et al., 2015). Besides the memory processes that take place, attention capacities should also be taken into consideration.

In the study by Ganis and Patnaik (2009), a Rapid Serial Visual Presentation (RSVP) was used which contained random faces and a famous face. What was found in their experiment was, that the participants' accuracy in reporting the appearance of the target face was decreased when the famous face also appeared in the RSVP trial. The results of this experiment support that when seeing a stimulus like a face that is already familiar to us, automatically draws some of our attention resulting in having fewer attention resources.

RSVP was further used to test if a salient item could evoke a physiological reaction compared to unfamiliar stimuli. In more detail, Bowman et al. (2013), in their study, let the participants choose a fake name to focus on, which along with their real name, could be seen in a RSVP of 15 items. The words were presented on the fringe of awareness (i.e., below the threshold of attention), which means they could only see a few names in a second. The researchers found that while unfamiliar names did not elicit a P3 component in the EEG signal, the fake name and their real name did elicit one. The research results support the idea that a salient item, which in this case was the participant's real names, is enough to create a physiological reaction. Moreover, from the results of the experiment, it can be supported that the reaction was caused by the real names shows that this stimulus was recognized and managed to break into consciousness.

Another method that was used in order to detect familiarity with a stimulus was the combination of the Fringe-P3 method with a concealed information test (Harris et al., 2021). In their study, the participants were shown a RSVP that contained different email addresses and they had to focus on a given email address which was the target, and report when they saw it. Among the email addresses, there was their own which was the secret target that was measured (probe). The results of the study showed a P3 response when the participants saw their own email addresses but not when they saw other irrelevant, unfamiliar addresses. The

significant results that were found for both the group and the individual level support the idea that this method can have promising results in detecting familiarity.

A different method to examine physiological responses when met with a familiar stimulus instead of EEG is pupillometry with the combination of RSVP. Previous studies (Fukunda, 2001; Leal & Vrij, 2010) examined blink rate and found a correlation between this and deception. A higher blink rate was found when the participants saw the "secret" target or the stimuli they were familiar with, but they did not have to pay attention compared to the control group. Continuing with the use of pupillometry and RSVP in an attempt to distinguish familiar stimuli from the unfamiliar stimulus, Chen et al. (2021) measured the size of the pupil during an RSVP which contained the actual name of the participant, a fake name that they chose before starting the experiment and unfamiliar names which were used as distractors. They had to report if they saw their fake name during each trial. The participant's pupils dilated when they saw both their real name and the fake one but not while seeing the distractor names. The study results support the idea that pupil size can provide information about concealed information and suggest high reliability with the results found in the EEG study mentioned above (Bowman et al., 2013).

In our study, we want to investigate whether pupil size increases when participants are told to report if a given face was presented to them after seeing a series of different faces. It is hypothesized that their pupil size will have the same reaction (dilation) when they see a familiar face even when told not to pay attention to it. The results of this research could be important because it could add support to the hypothesis that by exposing someone to different faces in the fringe of awareness there will not be enough time to suppress the physiological reactions of the pupil. The current study will try to replicate the results that were found by Chen at al. (2021). The stimuli that will be used are random faces and a famous face which will be used as a replacement for the real name of the participants. We

expect to find a larger pupil dilation when the participants see the face that was chosen randomly (target) at the start of the experiment but also for the famous face (probe) that they will see compared to the random faces (distractors) for which we expect no difference in the pupil size.

Methods

Participants

53 English-speaking individuals took part in the experiment. All of them were first-year Psychology students (37 female and 15 male) at the University of Groningen in the age group of 18-24 (M = 19.62, SD = 1.25). Participants had normal or corrected to normal vision. Prior to the experiment, participants were instructed to avoid wearing dark eye make-up.

Ethics

This study was conducted following the guidelines of the World Medical Association Declaration of Helsinki (2013) and approved by the ethics committee of the Psychology Department of the University of Groningen (approval number: PSY-2122-S-0168). Informed consent was obtained digitally from all participants before participation, and they were allowed to take a picture of this screen. Oral debriefing was provided to all participants after participation.

Apparatus

Participants were instructed to place their heads on a chin rest with an adjustable height. The distance between them and a 27'' LCD Liyama PL2773H monitor was 60cm. The display resolution was 1280x720 pixels and had a refresh rate of 1000 Hz. RSVP was presented with OpenSesame (Mathôt et al., 2012) running on Windows. Participants used a QWERTY keyboard to indicate their responses. The size of participants' pupils was recorded

in arbitrary units by an EyeLink 1000 (SR Research, Canada) during each trial using PyGaze (Dalmaijer, E., et al. 2014). Analyses were performed in JASP (2022) and RStudio (2022).

Stimuli

We selected faces for the experiment from the *10K faces database* (Bainbridge et al., 2013). More specifically, the total number of faces included in the RSVP was 1127. Prior to the experiment one of these faces was randomly selected for each participant to be the target stimulus. As the probe stimulus, a photo of Barack Obama (Figure 1a, Souza, 2012) was placed in the stream. Irrelevant distractor faces in each trial were selected randomly from our overall list of faces. A control face was also randomly selected for each participant before the experiment to check whether there would be no difference with the no target condition. This was done to ensure that a random face – equal in presentation frequency to the probe and target – would not become familiar and elicit a pupil dilation. Pictures were all monochrome and did not represent any body part of the person besides the face. All faces were presented in the center of a gray-colored screen inside a fixed oval shape (140 x 200 pixels), as shown in Figure 1a-b. The visual angle for each picture was 11.42° in height and 6.82° in width. Using custom Matlab scripts the photo of Obama was processed to appear similar to the unfamiliar faces in, for instance, contrast and brightness.

Figure 1a-b.

Examples of stimuli.

Note. Figure 1a shows the face of Barack Obama (Souza, 2012). Figure 1b shows a face used as a stimulus (Bainbridge, 2013).

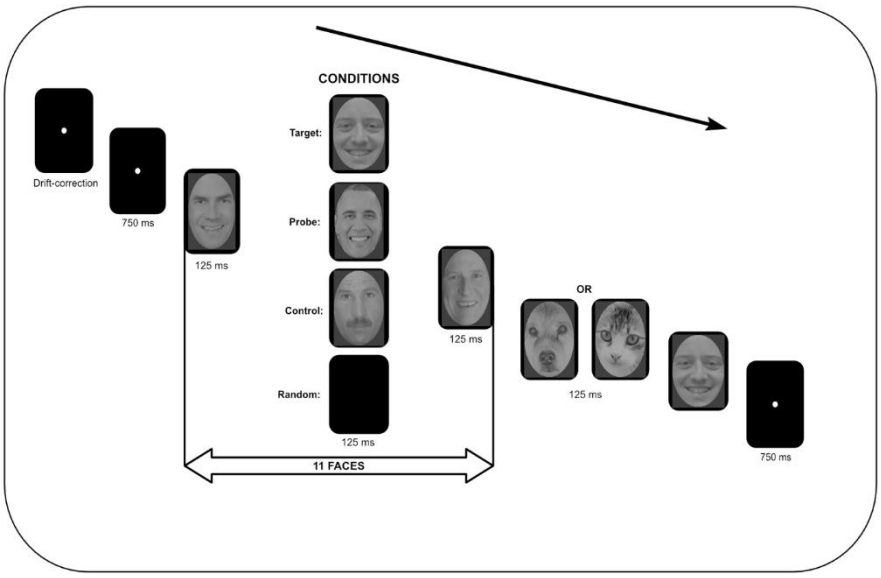
Procedure

After inspecting the pupil traces, we decided on a cut-off value of five or more removed trials in the processed data due to blinks. We calculated it by removing any participant who had exceeded three median absolute deviations from the median (*Mdn* = 1, *MAD* = 1). As a result, the data of 10 out of 53 participants was deleted, leading to a final inclusion of 43 participants.

Prior to the start of the experiment, participants were shown the target face and were required to finish ten practice trials to get familiar with the task. The experiment consisted of three consecutive blocks and each block of trials consisted of 32 trials resulting in a total of 96 trials. As shown in Figure 2, before each trial a fixation dot was shown for approximately 500-1000 milliseconds to capture the attention of the participant and to enable a baseline pupil size. The participants were then shown 11 faces concluding the trial with either a cat or a dog in an RSVP stream, each for 125 ms. During the stream, four conditions were possible. Participants were either shown the target face, the probe, a control face or no target face, which was presented randomly on position 5, 6 or 7 for every trial. After the sequence of faces, either a dog or a cat was shown to keep the participant's attention fixed throughout the entire stream. Finally, another fixation dot was presented. Overall, the RSVP trial duration was 3000 ms counting from the first to the last fixation dot.

Figure 2.

Visual Representation of a Singular Trial Sequence



Tasks

After each RSVP, the participants were initially asked to indicate whether a picture of a dog or a cat was shown. This was done to ensure the participant remained focused during the whole trial. They were instructed to press '*m*' to indicate if they saw a dog and press '*c*' if they saw a cat. After this first task, the target face was shown once more and the participants were asked *"Did you see this face?*". When they did not, they had to press '*c*' and when they did, they had to press '*m*'. The order of response buttons was counterbalanced over participants. After each response, the participant was shown whether they were correct or incorrect. The answer to the first question would either lead to an increase or decrease of the total score by five points. The answer to the second task, of whether they had seen the target face, resulted in either 10 points increase or 10 points decrease.

At the end of the experiment, the participants were given two questions. These were *"Did you notice the face of a famous person was shown sometimes?"* and *"If you had to guess which famous person we showed, who would it be?",* respectively. The latter, which was an open question, was added to ensure that participants who selected '*yes*' on the former question did, in fact, see Obama.

Design

In the RSVP sequence, 11 faces were shown. There were four conditions, one where the target face was present, one where the probe (Obama) was present, a condition where no target was present and a condition where a control face was presented. This control face was randomly selected from the database and served as a baseline that was similar in presentation frequency to the target and the probe. Each condition was shown either on position 5, 6 or 7. The four conditions in combination with three possible positions, and two possible animals resulted in 24 different combinations. Each possible combination was presented four times which resulted in 96 trials.

Data processing and analysis

To determine to what extent participants were able to sustain their attention during the trials, we first analysed the accuracy of the responses to the question of whether they saw a dog or a cat at the end of each trial. We then baselined the pupil sizes by taking the average size from the first three samples in each trial after the T1 presentation and subtracting this baseline value from all other samples in that trial. The window that has been chosen for the analysis is based on the study from Göl, Jansen and Rasztar (2022), where it was found that the biggest difference in pupil response occurs between 640 ms and 920 ms after the T1 presentation.

As an exploratory analysis, we used a Shapiro-Wilk test for the normality assumption. Afterwards, we used two nonparametric Mann-Whitney U tests on the group level to check for differences that may exist in the pupil size. In more detail, we used the means of the baseline-corrected pupil size [during the analysis window] as a dependent measure and condition as a fixed effect, to find if a difference exists between the pupil sizes when comparing target with no target, probe with no target and control with no target.

Results

In our study, we had two predictions. First, we checked whether the pupil size would be larger after the target face was presented, in comparison to when no target was presented. This would indicate that the task-relevant stimulus, the face that the participant had to actively look for, elicited a reaction that can be detected by using pupillometry in an RSVP. The second prediction was related to the detection of the famous face. If the pupil size in the probe condition would be larger than in the no target condition, then it would entail that the task-irrelevant, familiar face (even if subliminal) had elicited a physiological reaction. Supported by the results of the experiment, this prediction could provide support for the use of pupil size and RSVP in order to detect subliminal salience, or even concealed information.

Task Performance

On average participants were able to respond well above the guessing rate in both tasks. Regarding the first task (question: "*Did you see a cat or a dog?*") participants were able to indicate with an accuracy of 99% whether a picture of cat or a dog was shown at the end of the RSVP. When we inspected the performance on the second task (question: "*Did you see this face?*" accompanied with the target face). Participants responded correctly to the presence of the target in 57% of the cases and to the absence in 95% percent of the cases. To the two end questions *"Did you notice the face of a famous person was shown sometimes?*" and *"If you had to guess which famous person we showed, who would it be?*", of the 43 participants 38 gave an answer (79%) and of these 38 participants 45% indicated that they saw Obama.

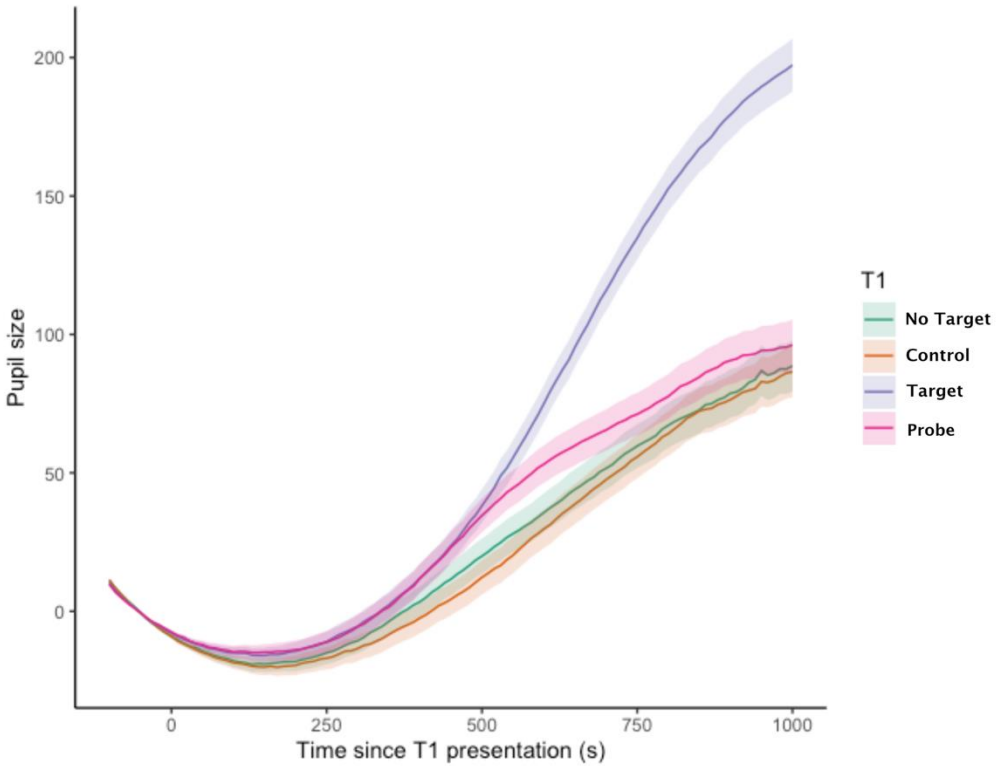
Pupil traces

Pupil traces in response to the presentation of T1 are shown in Figure 3. Visual inspection of the pupil size after the presentation of the target face shows a difference starting from approximately 500ms and showing an upwards trend until 1000ms. Likewise, the pupil

response to the presentation of the probe diverged from no target after approximately 500 ms. This effect, however, is not as large compared to the target condition. Inspecting the Control and the no target condition does not show a big difference.

Figure 3

Pupil trace visualization for the four conditions



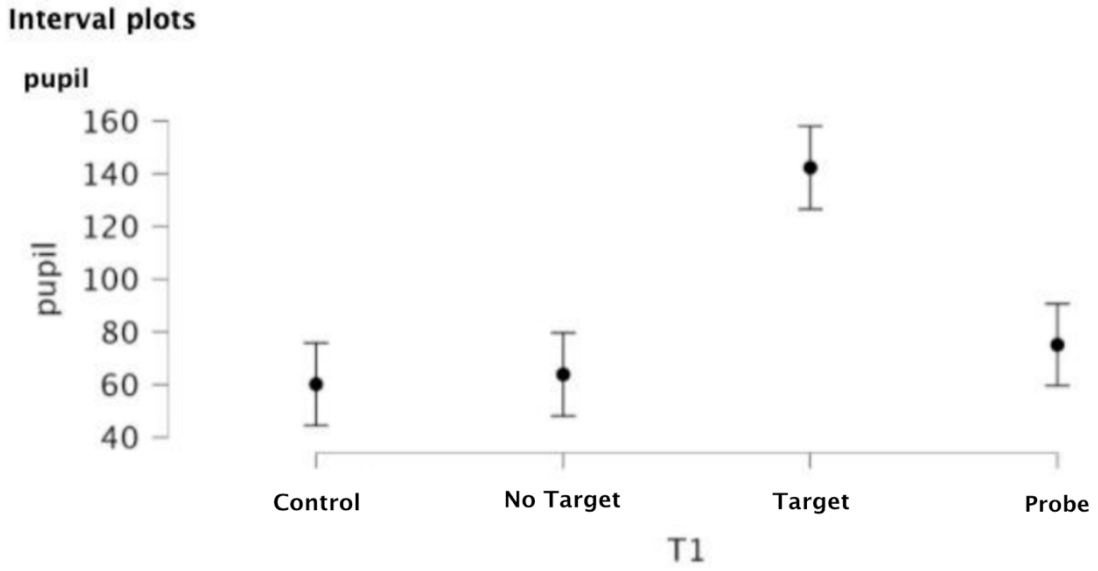
The mean values of participant's pupil sizes in the four different conditions were measured in the time window of 640 to 920 ms. The four conditions and their respective mean values, control (M = 60.15, SD = 253.28), no target (M = 63.88, SD = 255.76), target (M = 142.18, SD = 254.12), probe (M = 75.12, SD = 251.48) can be seen in Figure 4.

As the normality assumptions were violated, for the group level analysis two Mann-Whitney U tests were conducted to investigate differences in pupil size between the target, the probe and the no target condition. According to our first hypothesis, pupil sizes in the target condition would be larger compared to the no target condition. A significant difference

between target – no target supported our hypothesis (U = 412934, p < .001, d = -0.179). For the comparison probe – no target a non-significant p-value was found (U = 490915, p = .246, d = -0.030). This result does not support our hypothesis that in the trials in which the probe was presented, a larger pupil than in the no target condition would be observed. Lastly, we tested whether there was a significant difference between the control and the no target condition. A significant difference between these two conditions would indicate that participants became familiar with the control condition as well. This difference, however, was non-significant (U = 496888, p = .584, d = -0.014).

Figure 4.

Mean pupil size during the window of 640-920 over four conditions.



Discussion

Our main hypothesis was that the probe would elicit a dilation of the pupil significantly bigger than the no target condition, something that would add more evidence to the fact that pupillometry in combination with RSVP can be used as a substitute to the EEG in order to detect subliminal knowledge. The second hypothesis was that the target face would cause a significant pupil size effect in comparison with the no target condition, a result that would show that the participants were able to process the critical items and the

manipulation of the experiment is correct. Regarding the main hypothesis, while an upwards trend was found comparing the probe and the no target condition, this effect was not found to be significant. On the other hand, a significant difference in pupil size was found between the target and the no-target condition supporting the second hypothesis.

A difference in pupil size was noted when participants saw the probe which further supports the familiarity effect when seeing famous faces (Bentin & Deouell, 2000; Eimer, 2000; Touryan et al., 2011). However, the difference that was observed in the pupil size was not found to be significant as we hypothesized. Our results go against the results of Chen et al., (2021). In their study, the researchers used names instead of faces. When the participants were shown the probe (their real names) the pupil dilation was found to be significantly different from the pupil size of the no target (random names). From their results, it can be supported that pupillometry can be used instead of EEG, with the combination of RSVP in order to detect if someone is familiar with a stimulus and as a result provide information about concealed information.

Previous studies that were conducted using Obama's name or face in an RSVP (Alsufyani et al., 2021; Alsufyani et al., 2019) using EEG both supported the fact that showing people salient names or faces on the fringe of awareness generates a P3 component in contrast to names or faces that are unfamiliar to the participant. In more detail, in the study by Alsyfyani et al., 2019 the participants were shown different faces which could be a probe (Obama) a target face, a control face and unfamiliar faces. While the participants were told to respond only if they saw the target face, a P3 component was found when they were shown the face of Obama meaning that this stimulus managed to break into awareness and cause a physical reaction different from the one observed when presented with the unfamiliar face or the control face. The significant difference that was found between the probe and the no

target condition contradicts our findings which as already mentioned showed a difference between these conditions which was not found to be significant.

Some of the strong points of this research are that further support can be added to the fact that pupillometry instead of EEG can be also used with the combination of RSVP as a more practical way in order to detect if someone recognizes a salient face and he is able to process it. Moreover, another advantage that comes as a result of the combination of pupillometry and RSVP is that this method seems to be immune to countermeasures thus adding support to the use of this method as a reliable way to test for recognition of familiar stimuli.

However, some design modifications could be suggested in order to further explore the hypotheses that were tested in this research and go beyond some of the limitations of this study. The research design could be modified in order to increase the percentage of the participants that were able to distinguish the target since the accuracy of the participants was 57%. It is suggested to raise the RSVP duration and as a result, make it easier for the participants to notice the target face. As a result, this may also increase the percentage of the participants that may report seeing the probe which the percentage was 45% in this study. Moreover, something that should also be taken into consideration is that some participants may have by chance gotten “easy” or “difficult” target faces at the start of the experiment. For example, a face with facial hair could be characterized as more distinguishable from a face that does not have. Having an “easier” face as a target face could result in higher accuracy rates when it comes to reporting if the given face appeared or not. On the other hand, a participant that would have a “difficult” face might be less accurate in reporting the appearance of the target face.

Something that should also be taken under consideration is that while Obama is familiar to a lot of people, there is a chance that some participants did not know him or were

not highly familiar with his face resulting in being just a random face for them and not a face they already know. Inferentially, another face could be used that is more familiar to them such as a family member in order to achieve a higher recognition percentage.

In conclusion, the pupil size showed a trend of dilation when seeing the probe (Obama) in the RSVP task but the difference was not found to be significant comparing it to the no-target. This trend can be further investigated with the design and analysis modifications that were proposed above with the aim of exploring further the correlation between concealed information and pupil size when showing familiar stimuli using RSVP and pupillometry.

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