Establishing the duration of crimes: An individual differences and eye-tracking investigation into time estimation

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Abstract

The time available for viewing a perpetrator at a crime scene predicts successful person recognition in subsequent identity parades. This time is usually unknown and must be derived from eyewitnesses' duration estimates. This study therefore compared the estimates that different individuals provide for crimes. We then attempted to determine the accuracy of these durations by measuring observers' general time estimation ability with a set of estimator videos. Observers differed greatly in their ability to estimate time, but individual duration estimates correlated strongly for crime and estimator materials. This indicates it might be possible to infer unknown durations of events, such as criminal incidents, from a person's ability to estimate known durations. We also measured the eye-movements to a perpetrator during crimes. Only fixations on a perpetrator's face related to eyewitness accuracy, but these fixations did not correlate with exposure estimates to this person. The implications of these findings are discussed.

Introduction

Criminal investigations frequently rely on eyewitnesses to identify the perpetrators of an observed crime. In the UK, this is typically achieved by asking a witness to pick a perpetrator from an identity parade, in which a suspect is placed among other people (see PACE Code D). In many of these cases, eyewitnesses provide an accurate method for proving the identity of a person that was seen at a crime scene. However, many eyewitnesses also make honest errors under these conditions, by mistakenly identifying innocent suspects for a previously seen perpetrator (see, e.g., Davies & Griffiths, 2008; Huff, Rattner, & Sagarin, 1986; Wells, Memon, & Penrod, 2006). A fundamental problem in criminal person identification therefore concerns the extent to which it is possible to assess the accuracy of an eyewitness's memory for a sought-after perpetrator. In this context, eyewitness accuracy depends primarily on three pieces of information. These comprise (1) the strength of the initial memory that an eyewitness has formed for the appearance of a perpetrator at a crime scene, (2) the time interval over which this information has to be retained between the initial exposure to this person and a subsequent identity parade, and (3) the rate at which the perpetrator's appearance is forgotten. In criminal investigations, the retention interval can usually be specified with some precision. The precise nature of the forgetting function can now also be estimated reasonably well with sophisticated models of human memory (Deffenbacher, Bornstein, Penrod, & McGorty, 2008). What remains to be established therefore is an estimate of an eyewitness's initial memory strength for the appearance of a perpetrator.

An important situational determinant of this initial memory strength is the exposure duration to a perpetrator at a crime scene. Investigations of this variable show that longer exposures to a perpetrator consistently result in higher recognition accuracy than shorter exposures (for a recent meta-analysis, see Bornstein, Deffenbacher, Penrod, & McGorty, 2012). This effect is found, for example, in highly-controlled laboratory experiments in which observers have to remember static faces for a subsequent recognition test (e.g., Busey, Tunnicliff, Loftus, & Loftus, 2000; DiNardo & Rainey, 1991; Longmore, Liu, & Young, 2008; McKelvie, 1981; Read, Vokey, & Hammersely, 1990), in studies in which observers view video footage of simulated crimes or partake in live interactions (e.g., Memon, Hope, & Bull, 2003; Read, 1995), and in archival studies of police data from actual criminal identifications (Valentine, Pickering, & Darling, 2003).

Intriguingly, while the effect of exposure duration has been well established in the study of eyewitness identification, the actual exposure to perpetrators in real crimes is seldom known. The influence of this variable must therefore be determined by asking eyewitnesses to estimate this duration. In the study of eyewitness identification, it has been acknowledged for several decades that these estimates may differ from the actual exposure time and therefore need to be used with caution in criminal investigations (see, e.g., Burt, 1993; Loftus, Schooler, Boone, & Kline, 1987; Yarmey & Yarmey, 1997). By contrast, the alternative view, that it might be possible to establish the exact exposure duration through scientific method, is still rarely entertained. As a consequence, there remains only limited data concerning the ability of eyewitnesses to estimate the duration of a criminal encounter. Of the few existing studies in this field, some have focussed on group differences in time estimation abilities. These studies indicate, for example, that observers might typically overestimate the duration of short criminal events of 15 or 30 seconds, and female observers provide greater overestimates than males (see, e.g., Loftus et al., 1987; Yarmey, 1993). Other studies suggest that the perceived duration of events is not affected by language use prior to time estimation (Pedersen & Wright, 2002), but might be improved by recall techniques such as mental imagery rehearsal (Yarmey & Yarmey, 1997).

These studies are useful for showing how observers behave *generally* during time estimation, but provide little insight to which extent it might be possible to determine exposure duration for a *specific* incidence. Moreover, in the field of eyewitness identification, the role of individual differences in time estimation ability has largely been ignored. This is an important issue as other domains have not only shown that duration estimates for short time intervals are often inaccurate, but also that considerable individual differences exist in the ability to estimate time (see, e.g., Block, Hancock, & Zakay, 2000; Brown, 1998; Espinosa-Fernandez, Miro, Cano, & Buela-Casal, 2003; Fink & Neubauer, 2005). If similar principles apply to time estimation in criminal incidents, then some observers might be able to report these durations accurately while others cannot. The difficulty arises in differentiating these types of eyewitnesses.

The current study represents a first attempt to investigate this problem, with a simple process. We first showed observers video footage of two recorded crimes, which lasted for 32 and 64 seconds, and recorded their estimates for the duration of these events. We then sought to establish the accuracy of the reported crime durations. Importantly, our aim was not to establish this accuracy from our prior knowledge of these durations, as such privileged information is typically not available in criminal incidents. Rather, we sought to establish the accuracy of duration estimates by assessing a person's *general* time estimation abilities. For this purpose, observers were also asked to report the perceived duration of ten estimator videos, which varied systematically in length from 16 to 80 seconds. We then examined the relationship between their accuracy in estimating the duration of the crimes with their general time estimation abilities, to determine if the former could be inferred from the latter.

In an additional step, we also sought to examine whether an eyewitness's perception of the duration of a criminal event relates to the actual amount of time for which a perpetrator was viewed and, in turn, how this relates to identification accuracy. For this purpose, we monitored observers' eye movements during the viewing of the crime videos and recorded the proportion of fixations that landed directly on the perpetrator. We then compared these direct viewing measures with the estimates of viewing time and with eyewitness identification accuracy.

Method

Participants

Ninety-eight students (29 male) from the University of Kent volunteered to participate in the experiment in exchange for course credit or a small payment. The participants had a mean age of 21.5 years (SD = 4.2 years).

Stimuli

The eyewitness task

In this experiment, two staged crime videos depicting two different perpetrators (here referred to as A and B) were used. Both videos depicted a non-violent burglary, in which a single perpetrator was shown entering a house and searching through the contents. Each of these videos was edited to produce a short version of the crime lasting 32 seconds and a long version of 64 seconds. Most studies that have investigated the effect of exposure on person recognition with video stimuli employed durations of between 12 and 200 seconds (e.g., Boyce, Lindsay, & Brimacombe, 2008; Foster, Libkuman, Schooler, & Loftus, 1994; Memon & Gabbert, 2003; Memon, Hope, & Bull, 2003), and the durations for the current study were selected to fall within this range.

Participants were randomly assigned to view two of these videos, which always consisted of one video of perpetrator A and one of perpetrator B, and of a short and a long exposure. Over the course of the experiment, the administration of these videos was counterbalanced so that each perpetrator was shown in each exposure condition an equal number of times.

For the identification phase, high-quality colour photographs of faces were arranged in two 5 x 2 arrays, which comprised the photograph of a criminal (person A or B) and nine similar looking filler identities. The fillers were taken from the Glasgow University Face Database (Burton, White, & McNeill, 2010) and were chosen by the experimenters to be of similar age and general appearance to the culprit. In the lineups, all of these faces were presented at a size of approximately 4.5 x 6 cm and with a neutral facial expression.

The general time estimation task

Ten further videos were prepared for the general time estimation task. Five of these videos showed car-chases, which were taken from movies. The other five videos consisted of aquatic scenes, which were recordings of fish tanks. These contrasting categories were employed as duration estimates can depend on additional variables, such as the complexity and interest value of observed material (e.g., Block & Zakay, 1997; Ornstein, 1969; Schiffman & Bobko, 1974). As a small side aim, we therefore decided to contrast car chases (which might be perceived as relatively entertaining) with aquatic scenes (which might be seen as comparatively boring) to assess if this video content would affect the estimation process for the criminal incidents. The five videos for each category varied in duration from 16 to 80 seconds in 16-second intervals (i.e., 16, 34, 48, 64, and 80 seconds). As we sought to obtain a measure of time estimation ability that was directly comparable across individuals, this content was applied equally across observers. The videos were therefore always shown in the same predetermined sequence, which alternated aquatic scenes and car chases and counterbalanced the durations (i.e., 80s Aqua, 32s Car, 48s Aqua, 64s Car, 16s Aqua, 16s Car, 64s Aqua, 48s Car, 32s Aqua, 80s Car).

Procedure

Participants were fitted with an SR-Research Eyelink II head-mounted eye-tracking system running at 500 Hz sampling rate. Viewing was binocular but only the participants' dominant eye was tracked. The tracker was calibrated using the standard Eyelink procedure. Thus, participants fixated a series of nine fixation targets on the display monitor. Calibration was then validated against a second series of nine fixation targets, and if this indicated poor measurement accuracy, calibration was repeated.

In the first part of the experiment, participants then watched the first crime video, which lasted for either 32 seconds or 64 seconds (depending on the condition they were assigned). Immediately following the viewing of the first crime video, the observers were given a surprise test in which they were required to estimate the duration of the video and then also the duration of the visibility of the perpetrator. Following this, the observers were given a filler task (counting letters on a sheet of paper), which lasted a few minutes, and were then given the appropriate identity lineup for the perpetrator of the videoed crime. While these lineups always included the target, the participants were told that the perpetrator could be present or absent in the line-up. They were therefore asked to indicate whether the perpetrator was present, and if so, identify who he was. This procedure was then repeated for the second crime video. Note that our participants were therefore completely unaware that this study assessed time estimation prior to watching the first crime video, but were probably aware of this aim thereafter.

In the second part of the experiment, the participants were then shown the ten general time estimation videos. After each video, the participants were asked to provide an estimate for the duration of this footage. The participants were emphatically told to refrain from counting time during the showing of these videos, but to provide a measure of their perceived or 'felt' sense of duration.

Results

Duration estimation

The main aim of this study was to determine the accuracy of eyewitnesses in estimating the duration of staged crimes from their time estimates for videos of car chases and aquatic scenes. The cross-subject means of the duration estimates for these movies are shown in Figure 1. All of these estimates appear to match the actual duration of the videos closely and correlate strongly with these, $r(12) = 0.952$, $p < 0.001$. This indicates that, as a group, observers were generally accurate at perceiving the differences between durations. However, from the standard deviation of the means in Figure 1 it is also clear that these average estimates were undermined by substantial variation between individual participants. For example, this variation was such that duration estimates varied between 7 and 120 seconds for the short crime videos of 32 seconds, which corresponds to a range of 22% to 375% of the actual duration of the video. Similarly, for the long crime videos of 64 seconds, duration estimates varied between 10 and 300 seconds, or a range of 16% to 469% of the video duration. Crucially, however, the duration estimates also correlated for the two crime videos, $r(98) = 0.655$, $p < 0.001$, and across all of the estimator videos, with Pearson's r

coefficients ranging from 0.507 to 0.867, all *p*s < 0.01 (mean *r* = 0.713). Thus, while there appears to be substantial interindividual variation in duration estimation, individual observers appear generally consistent in their tendencies to under- or overestimate time.

Importantly, a similar relationship was found when the durations for the estimator videos were compared directly with those for the crime videos. For this analysis, we first combined the data from the car chases and aqua scenes, and then examined the relationship between these duration estimates with the estimates for the crime videos (see Figure 2). This analysis showed that the perceived durations of the 32s estimator videos (which is the mean of the scores for the 32s aquatic scene and the 32s car chase) correlated well with the durations for the 32s crime videos, $r(98) = 0.620$, $p < .001$. Similarly, the perceived duration of the 64s estimator videos also correlated with the 64s crime videos, $r(98) = 0.497$, $p < .001$. These correlations also appear to be robust across the different categories of estimator movies. For example, the duration estimates for the 32s crime videos also correlated individually with the duration estimates for the 32s aquatic scene, $r(98) = 0.595$, $p < 0.001$, and with the 32s car chase, $r(98) = 0.585$, $p < 0.001$. Likewise, the duration estimates for the 64s crime videos correlated with the duration estimates for the 64s aquatic video, $r(98) = 0.476$, $p < 0.001$, and the 64s car chase, $r(98) = 0.463$, $p < 0.001$.

In addition, we also compared the time estimates for the 32s and 64s crime videos with observers' overall accuracy for the estimator videos. This overall accuracy measure was obtained by calculating the difference between the perceived and the actual duration of each estimator video, and by taking the average of these differences across all estimators videos. As for the 32s and 64s estimator videos, robust correlations were found between this overall measure of time estimation accuracy and the duration estimates that observers provided for the 32s crime videos, $r(98) = 0.618$, $p < .001$, and the 64s crime videos, $r(98) = 0.538$, $p < 0.001$.

Finally, we also transformed the duration estimation data by grouping observers according to whether they estimated the duration of the crimes accurately[1], or under- or overestimated the duration of these events. This data was then compared to the equivalent breakdown of the corresponding estimator videos. In Figure 3, this data is transformed into probabilities that illustrate the interplay of both sets of estimates. By comparison to the correlations illustrated in Figure 2, this data provides a more accessible means to infer the likely estimation behaviour of an eyewitness. For the long crimes, for example, Figure 3 shows that the majority of observers who underestimated the duration of the estimator videos also underestimated the duration of the 64 second crime (probability = 0.68), while the remaining participants were somewhat likely to estimate the duration of the crime exactly (0.24), and highly unlikely to overestimate the crime duration (0.08). Conversely, when observers overestimated the duration of the estimator videos, they were also more likely to overestimate the duration of these crimes (0.54), than to underestimate (0.25) or accurately estimate crime duration (0.21).

Taken together, the data reported here demonstrate that substantial individual differences exist in time estimation. However, observers appear to be broadly consistent in whether they can accurately estimate, or over- or underestimate time. This indicates that it might be possible to infer the duration of an 'unknown' event, such as a

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[1] Note that none of the observers managed to estimate the duration of the crime videos within a +/- 5% margin of the actual crime duration. For this analysis, we therefore defined accurate duration estimates as those that were within a +/- 10% margin of the actual crime duration. For example, for the short crime videos of 32 seconds, this corresponds to an interval of 28.8 to 35.2 seconds. We applied the same parameters to define accuracy for the estimator videos.

criminal incident that was observed by an eyewitness, by subsequently determining a person's accuracy in estimating the duration of known events.

Exposure to perpetrator

In the second part of the analysis, we sought to analyse estimates of exposure to the perpetrators and then compare these with the actual amount of time for which these persons were viewed. For this analysis, we first compared the observers' duration estimates for the crime videos with their time estimates for the visibility of the perpetrator. This data, depicted in Figure 4, shows that these estimates correlate closely for the 32 second crime video, $r(98) = 0.909$, $p < 0.001$, and also for the 64 second crime video, $r(98) = 0.950$, $p < 0.001$. Of course, one would expect these measures to correlate, as the duration estimate for the perpetrators should logically not exceed that for the videos.

More importantly, we also compared the time estimates for visibility of the perpetrator with the estimator movies. For this analysis, we combined the data from the aquatic scenes and car chases (as the time estimates for these movies correlated strongly), by taking the mean score of these two categories for the 32s and the 64s duration. This analysis is also illustrated in Figure 4 and shows that the time estimates for the perpetrator in the short crime videos correlated with the 32s estimator videos, $r(98) = 0.493$, $p < 0.001$, and, equally, for the long crime videos also correlated with the 64 seconds estimator videos, $r(98) = 0.596$, $p < 0.001$. In addition, the time estimates for the perpetrator in the short and long crime condition correlated also with the overall accuracy measure for all estimator videos, $r(98) = 0.507$, $p < 0.001$ and $r(98) = 0.644$, $p < 0.001$, respectively.

These results are therefore important for showing that the current approach, for assessing a person's time estimation ability, might not only be useful for establishing the duration of a criminal *event* but, more specifically, could be used also to determine whether a person is likely to under- or overestimate exposure to a *perpetrator*. The question remains, however, how these estimates relate to the actual extent for which a culprit was viewed. To address this issue, we calculated the duration for which each observer directly fixated the perpetrator in the crime videos and compared this with the time estimates for the perpetrator (see Figure 4). This analysis showed that the fixation duration on the perpetrator was not associated with the duration estimates in the 32s crimes, $r(93) = -0.052$, $p = 0.623$, and the 64 second crimes, $r(96) = -0.055$, $p = 0.597$. This suggests that observers do not directly base their exposure estimates for the perpetrator on the amount of time for which this person is fixated. We return to this finding in the General Discussion.

Exposure and accuracy

The final part of the analysis focused on the effect of exposure duration on identification accuracy. For this purpose, the long and short crime video conditions were divided into three groups according to the participants' performance on the lineup identification test. These groups corresponded to observers who correctly identified a target from an identity lineup (i.e., who made a 'hit' response), those who mistakenly identified another lineup face as the target (a 'misidentification'), and observers who incorrectly indicated that the target was absent (a lineup 'rejection').

Table 1 summarizes the percentage of these responses. This data shows that observers recorded more hits and fewer misidentifications in the long compared to the short crime videos. Overall, however, the effect of exposure duration on identification accuracy appeared to be small. The observations were confirmed with a series of chi-square tests, which found no difference between the crime conditions in hits, $\chi^2 = 0.273$, $df = 1$, $p = 0.60$, misidentifications, $\chi^2 = 0.182$, $df = 1$, $p = 0.67$, and lineup rejections, $\chi^2 = 0.013$, $df = 1$, $p = 0.91$.

In an effort to understand the absence of a reliable effect of exposure duration on identification accuracy, we conducted a frame-by-frame content analysis of the crime videos to code the duration for which the perpetrators were actually visible to the eyewitnesses over the period of the crimes. This analysis codes the visibility of the perpetrators' bodies and heads. In addition, the visibility of the face was also coded separately as an additional category, as the face provides the most reliable visual means for person identification (Burton, Wilson, Cowan, & Bruce, 1999) and draws and retains observers' attention (e.g., Bindemann & Burton, 2008; Bindemann, Burton, Hooge, Jenkins, & De Haan, 2005; Langton, Law, Burton, & Schweinberger, 2008). In the content analysis, this region of interest was defined as any views of a face in which at least one eye was clearly visible. This analysis is depicted in Figure 5 and shows that the perpetrator's head and body were visible for most of the time in the videos. By contrast, the faces were only visible for part of the crimes.

The extent to which the faces are visible in these crime videos should be related to eyewitness identification accuracy, as this was assessed by testing recognition of a perpetrator's face. We therefore analysed the fixations on the perpetrators' faces in the videos. The percentages of these fixations, averaged across observers, are illustrated in Figure 6. The peaks in this graph correspond directly to the video frames in which the perpetrator's face was visible (c.f. content analysis in Figure 5). This indicates that observers were attending to the perpetrators' faces when these became visible.

To determine whether this behaviour related to eyewitness identification accuracy, we compared the proportion of time of the crime video in which the perpetrators' faces was fixated for observers who recorded a hit, a misidentification or a lineup rejection in the lineup task. Due to low number of hits for the 32s and the 64s crime videos, and the fact that the perpetrator's face was actually visible for less time in the long version of Crime A (for 11.6 seconds, see Figure 5) than in the short version of Crime B (for 12.0 seconds), we combined all crime videos for this analysis. This analysis revealed that observers who recorded a hit attended to the perpetrators' faces for longer (17.3% of the total crime duration) than observers who made a misidentification (12.1%), $t(117) = 3.19$, $p < 0.01$, $d = 0.65$. In addition, the observers who recorded hits also attended to faces more than those who rejected the identity lineup (15.4%), but this difference was not reliable, $t(100) = 1.00$, $p = 0.32$, $d = 0.22$. Finally, the observers who recorded a misidentification also looked at the faces less than observers who made a lineup rejection, $t(161) = 2.55$, $p < 0.05$, $d = 0.40$. We also repeated this analysis with the fixations that were directed at any part of the perpetrator except for the face. This revealed that observers who recorded a hit also looked at the perpetrators' bodies for longer (56.4%) than those who recorded a misidentification (54.7%) or a lineup rejection (53.9%). However, these differences were much smaller than the differences in fixations on the perpetrators' faces and were not significant, all ts ≤ 1.00, all ps ≥ 0.32, all ds ≤ 0.21.

In summary, this analysis shows that the full duration of a crime is not equivalent to the exposure to a culprit, and this, in turn, may also not be equivalent to the exposure to a perpetrator's face (see Figure 5). However, when a perpetrator's face is visible, observers are drawn quickly to the face (see Figure 6). The extent to which this occurs appears to relate to eyewitness identification accuracy, as the observers who made a correct person identification from an identity lineup generally looked at a perpetrator's face for longer than those who identified the wrong person from a lineup as the target.

Discussion

The length of the exposure to a perpetrator at a crime scene is a primary determinant of an eyewitness's ability to recognize this person at a subsequent identification test in police investigations. In real crimes, however, these exposure durations are seldom known and can typically only be obtained by asking eyewitnesses to provide an estimate based on their felt sense of time. In this study, we therefore investigated if it might be possible to determine the accuracy of these estimates. For this purpose, we first asked observers to estimate the duration of two staged crimes, before obtaining time estimates for a further set of estimator videos. We then examined the relationship between observers' accuracy in estimating the duration of the crimes and the estimator videos, to determine if the former could be inferred from the latter.

While the cross-subject means of the duration estimates for all videos were remarkably accurate, a closer inspection of this data revealed broad individual differences in time estimation ability. For the short crime videos, for example, duration estimates varied between 22% to 375% of the actual duration. This range was even more considerable for the long crime videos, for which we obtained a range of duration estimates that corresponded to between 16% and 469% of the actual duration. This demonstrates that people can differ enormously in their duration estimates and emphasizes that such data must be treated with outmost caution in criminal investigations.

Crucially, however, we also found that people are quite consistent in making duration estimations. For example, we observed that duration estimates for the short and long crime videos and, likewise, for all of the estimator videos correlated well. This suggests that, while there appears to be substantial variation across participants, individual observers consistently under- or overestimate time. However, the most important finding here is that the reported durations for the estimator videos also correlated with those of the crimes. We transformed these correlations into probabilities that illustrate the extent to which it might be possible to determine the likelihood that an eyewitness has under- or overestimated a criminal event. These probabilities showed, for example, that if an observer underestimates the duration of the estimator videos, there is a 0.75 probability that they also underestimated the duration of the short crime videos. Conversely, if observer overestimated the duration of the estimator videos, they were also more likely to overestimate the duration of the short crime (0.48) than to underestimate its duration (0.34) or estimate it accurately (0.17). These probabilities are obviously restricted to the conditions of the current experiment and therefore do not allow us to determine the duration estimation accuracy of eyewitnesses in real criminal incidents. These data demonstrate, however, that this approach is a potential basis for further development, which could eventually provide some useful metrics for generating *more precise* duration estimates for real crimes.

We believe that this could be an important early step in the development of such methods. It has been known for many years that exposure duration is an important variable in eyewitness identification tasks (e.g., Bornstein et al., 2012; Memon et al., 2003; Read et al., 1990). Despite this, there have been no attempts so far to investigate how we can assess the accuracy of the exposure estimates that are given by a specific eyewitness. The current study suggests that this could be achieved simply by assessing a person's duration estimation ability, and we anticipate that this approach will be refined substantially with further research. It has already been shown, for example, that mental imagery rehearsal can improve duration judgments for crimes (Yarmey & Yarmey, 1997). The combination of such methods with the current approach promises further developments. By the same token, experimental time estimation research also shows that many factors affect the perceived duration of events. For example, a persons' experience of time can be altered by the stress, cognitive demand or arousal of an event (see, e.g., Loftus et al., 1993; Livesey, Wall, & Smith, 2007; Grondin, 2010). Thus, future research should also investigate how it might be possible to establish a person's time estimation accuracy across a range of conditions.

To this point, a specific question that arises from the current study is whether observers' duration judgements were influenced by an anchoring effect, whereby the duration of a just-provided estimate influences duration judgements for a subsequent event (see, e.g., Thomas & Handley, 2008). Such anchoring leads to the underestimation of an event when the preceding task was shorter, and to overestimation when the preceding task was longer (Thomas, Handley, & Newstead, 2004), and is found even when two successive tasks are structurally dissimilar (Thomas, Handley, & Newstead, 2007). To determine if anchoring might have affected duration perception in the current study, we compared the time estimates for the crime that observers were shown first with the crime that they were shown second. This comparison is poignant also as observer were initially unaware, while viewing the first crime video, that this study investigated time estimation, but were aware of this purpose thereafter, when viewing the second crime video and the estimator videos.

For this analysis, we measured the difference in accuracy between the estimates for the first- and second-seen crime. These scores were computed as a percentage of the overall crime durations, to make these directly comparable for the short and long crime videos. An ANOVA of this data with the factors group (short crime video seen first vs. long crime video seen first) and order (first-seen, second-seen crime video) found a main effect group, $F(1,96) = 9.05$, $p = 0.01$, partial $\eta^2 = 0.09$. This reflects the finding that observers who saw the short crime video first underestimated the duration of both crime videos (by -26%), while the group of observers who saw the long crime video first tended to overestimated these durations (by +8%). While this might provide some support for an anchoring effect, the absence of a main effect of order indicates that the time estimate for the first- and second-seen videos were generally evenly matched, $F(1,96) = 1.12$, $p = 0.29$, partial $\eta^2 = 0.01$, and the interaction between both factors failed to reach significance here, $F(1,96) = 3.17$, $p = 0.08$, partial $\eta^2 = 0.03$.

We also examined the estimator videos for a possible anchoring effect, by comparing the mean duration estimate for each video with its actual duration with a series of one-sample t-test, and by exploring whether preceding videos led to significant deviation in the duration estimates of subsequent videos (see data in Figure 1). These one-sample t-tests showed that the duration of the 32s car chase was overestimated following the presentation of the 80s aquatic scene, $t(97) = 3.68$, $p < 0.001$, $d = 0.32$, and the duration of the 64s aquatic scene was underestimated following the presentation of the 16s car chase, $t(97) = 2.76$, $p < 0.001$, $d = 0.28$. On its own, these differences could provide some support for an anchoring effect, but we also found that the duration for the 16s aquatic scene was underestimated after presentation of the 64s car chase, $t(97) = 4.81$, $p < 0.001$, $d = 0.49$, and none of the other mean estimates differed reliably from the actual video duration, all ts ≤ 1.59, all ps ≥ 0.12, all ds ≤ 0.16. Overall, we are therefore inclined to suggest that anchoring did not significantly affect duration judgements in the current task. At the same time, it is possible that the current procedure can be improved by a method that eliminates the possibility of such effects.

In a similar vein, it is also possible that the current method will be affected by the content of the estimator videos, as there is good evidence that duration estimates are affected by the complexity and interest value of stimulus material (e.g., Block & Zakay, 1997; Schiffman & Bobko, 1974). In the current study, we found no notable differences between aquatic scenes and car chases, despite the fact that these categories provide drastically different content. Indeed, we initially assumed that the aquatic scenes might be perceived as less entertaining than the car chases. However, we made no attempt to measure the interest value of our materials directly and some of our participants noted that these aquatic videos were rather captivating. It therefore remains to be seen if the content of different estimator videos can improve or hinder the current approach. For now, our findings point to an effect that is robust across the two categories of estimator videos that were used here.

In addition to the comparison of the crime and estimator videos, the current study provides a series of additional insights, as we also compared the observers' estimates for the exposure to a perpetrator with the amount of time for which these targets were actually viewed. This analysis showed that the duration estimates for the perpetrators did not correlate with the time for which they were fixated. The absence of this correlation perhaps seems initially surprising, particularly in the context of the consistent correlation between the estimator and crime videos. However, it is noteworthy that we adopted strict criteria for calculating the viewing time of the perpetrator, by only including fixations that landed directly on these targets. This analysis therefore excludes all instances in which the perpetrators were viewed parafoveally. It is well known that persons can still be processed in considerable depth under these conditions (see, e.g., Bindemann, Burton, & Jenkins, 2005; Jenkins, Lavie, & Driver, 2005). Moreover, other information such as body movement may provide additional cues in parafoveal vision that can help track the presence of a person (see, e.g., Abrams & Christ, 2003; Pratt, Radulescu, Mu Guo, & Abrams, 2010; Shaw & Skolnik, 1999). It therefore seems likely that observers were aware of the presence of the perpetrators even when they were not fixated directly, and that this may determine the duration estimates for viewing these targets instead. This notion receives support from the observation that the duration estimates for the perpetrator correlated closely with the estimates for the crime scenes, which suggests that observers either knew or assumed the perpetrator was visible throughout these incidents.

We also analysed the person content of the criminal incidents in more detail, and compared this with the extent to which observers *actually* view a perpetrator during a crime. This revealed some interesting findings. For example, we found that, while a perpetrator may be visible for almost an entire criminal incident, his face may only be visible for a small proportion of the time. In the current study, this produced some unexpected results as we found that the face of perpetrator A was actually visible for less time in the long crime video (11.6 seconds) than the face of perpetrator B in the short crime video (12.0 seconds). In this context, it is perhaps unsurprising that we failed to find a reliable effect of crime duration on eyewitness accuracy. By contrast, however, we also found that the extent to which observers fixated the perpetrators' faces relates to eyewitness identification accuracy, whereby the observers who made a correct person identification from the identity lineups looked at the perpetrators' faces for longer than those who identified the wrong person from a lineup as the target. These results therefore demonstrate that the duration of a crime is not equivalent to the exposure to a culprit, and this, in turn, is not equivalent to exposure to a culprit's face. Of these, exposure to the face appears to be most important, probably because this provides the primary identity-related information (see, e.g., Bindemann, Brown, Koyas, & Russ, 2012; Burton et al., 1999).

In light of these findings, it is interesting to note that, while strong exposure effects can be found consistently in studies using static photographs of faces (Shapiro & Penrod, 1986; Bornstein et al., 2012), the effect of exposure on eyewitness identification in studies with moving targets appears to be more inconsistent (see, e.g., Boyce et al., 2008; Gross & Hayne, 1996; Brigham, 1990). Our results might provide a simple explanation for these inconsistencies by demonstrating a critical distinction between the duration of a crime and, embedded within this event, the more *useful* exposure to a culprit's face. This distinction is likely to be enhanced particularly under more realistic viewing conditions, in which a person's face may occasionally disappear from a view. However, this distinction is rarely quantified in psychological experiments, as most tend to report the total event duration (e.g., Brigham, 1990; Foster et al., 1994) or only coarse estimates of the interaction between a witness and a target in live encounters (e.g., Read, 1995; Gross & Hayne, 1996). Our content analysis therefore provides a valuable opportunity to compare the *exact* exposure to a perpetrator with the overall duration of a crime. The addition of the eye movement data then reveals how this content is associated with eyewitness accuracy.

While these results suggest that measuring eye movements around a visual scene may not be sufficient to derive an accurate measure of a witness's exposure to a perpetrator, the fact that the proportion of time spend looking at the perpetrators' faces related to eyewitness accuracy indicates the importance of these direct inspections for person recognition. An interesting question that arises from these results is therefore how we should derive observers' estimates for the exposure to a culprit. For example, should eyewitnesses be asked about the duration of a crime, the duration of exposure to a perpetrator, or how long they directly focused on his face? At this time, it remains to be seen whether this issue is crucial for estimating the exposure to a perpetrator, or whether observers can even provide independent estimates according to these criteria.

In summary, the current study examined the relationship between observers' accuracy in estimating the duration of staged crimes with their general time estimation abilities, to determine if the former could be inferred from the latter. We obtained three main findings. (1) We found that substantial individual differences exist in time estimation but observers were also broadly consistent in over- or underestimating time. In future, this might make it possible to infer whether a person is under- or overestimating the 'unknown' duration of an event, such as a criminal incident that was observed by an eyewitness, from a person's accuracy in estimating the known duration of a subsequent series of events. Hopefully, our work provides a useful starting point here. (2) However, while it is also possible to assess the likely accuracy of time estimates for the exposure to a perpetrator, these estimates do not correlate with the proportion of fixations that an observer orients directly at the perpetrator. It seems likely that this discrepancy arises because the perpetrator can still be viewed parafoveally. (3) Finally, the duration of a crime is not equivalent to exposure to a perpetrator and this, in turn, is not equivalent to exposure to a perpetrator's face. This distinction appears to be important as observers are drawn to the face, and the extent to which this occurs relates to eyewitness identification accuracy. For future research, this raises the question of how exposure to a perpetrator needs to be defined in eyewitness settings, and of how an eyewitness's perception of the exposure duration to useful identity-related information should be probed. Equally, it remains to be seen if the current approach for establishing estimation accuracy is robust when other factors affecting our sense of time are taken into account.

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TABLE 1. Eyewitness Identification Accuracy for Short (32 Seconds) and Long (64 Seconds) Crimes, and the Difference between these Conditions

	Crime duration		
	32 seconds	*64 seconds*	*Difference*
Hits	15.3	18.4	3.1
Misids	46.9	42.8	-4.1
Misses	37.8	38.8	1.0

FIGURE 1. The cross-subject means of the duration estimates for the crime videos, aquatic scenes and car chases. Error bars show standard deviation around the means.

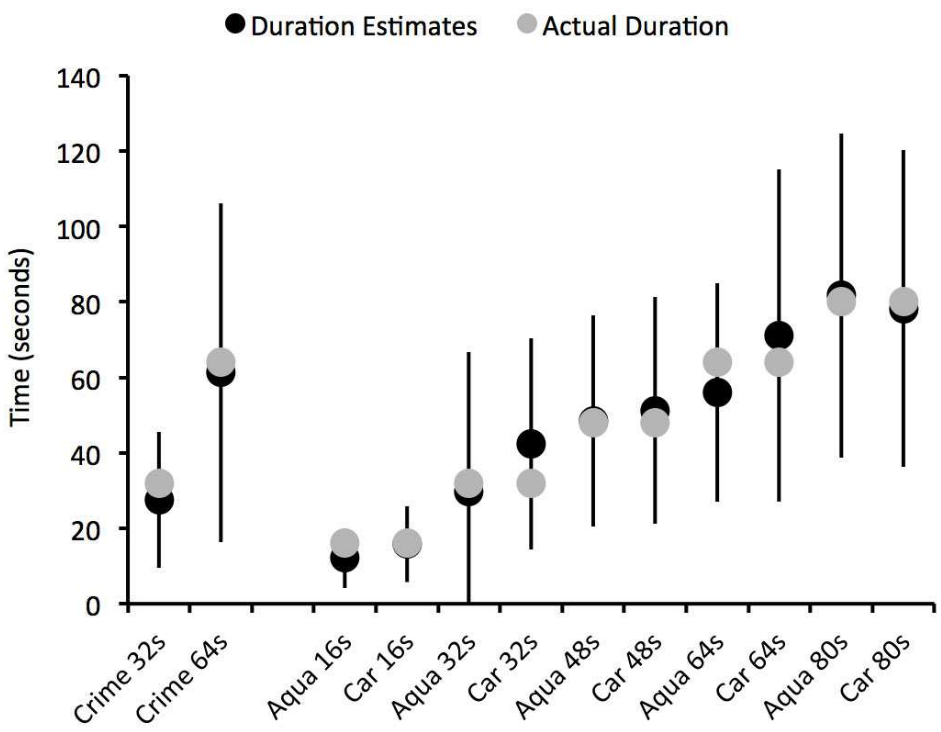

FIGURE 2. Correlations of the duration estimates for short (32 seconds) and long (64 seconds) crimes and the duration estimates for the corresponding aquatic scenes (middle column) and car chases (right column), and the mean of the duration estimates for both categories of estimator movies (left column). Note: graphs are capped at 100/200 seconds and therefore do not show a small number of more extreme values (N = 3).

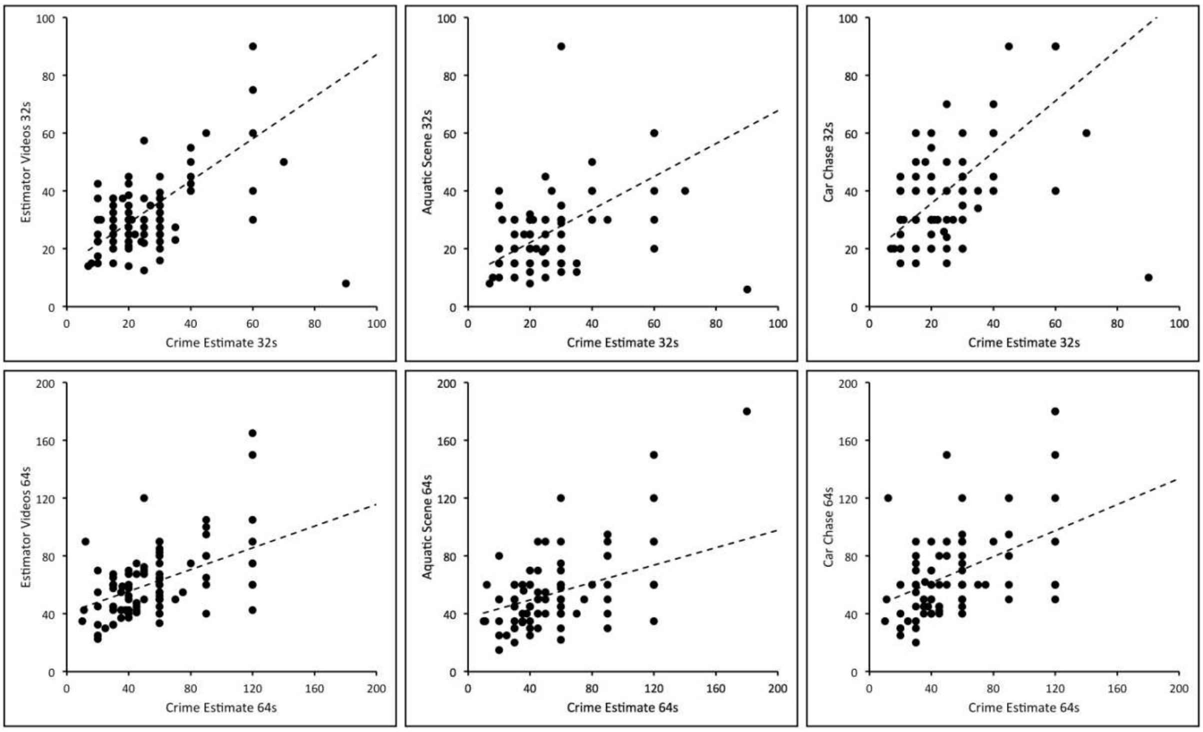

FIGURE 3. The probability of accurately estimating, or under- or -overestimating the duration of the short and long crimes, given a person’s tendency to accurately estimate, or under- or overestimate the duration of the corresponding estimator videos.

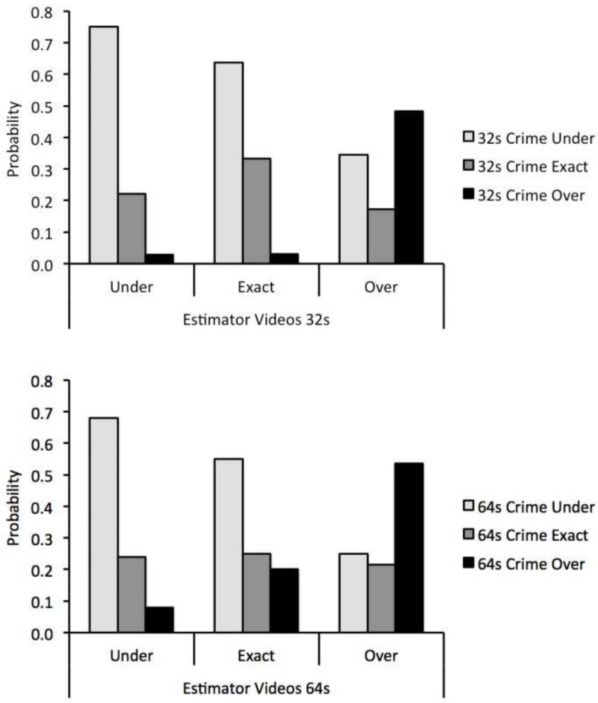

FIGURE 4. Correlations of the duration estimates for the visibility of the perpetrator in short (32 seconds) and long (64 seconds) crimes and the estimates for the crime duration (left column), and the corresponding estimator videos (middle column), and the fixation duration on the perpetrator (in seconds; right column).

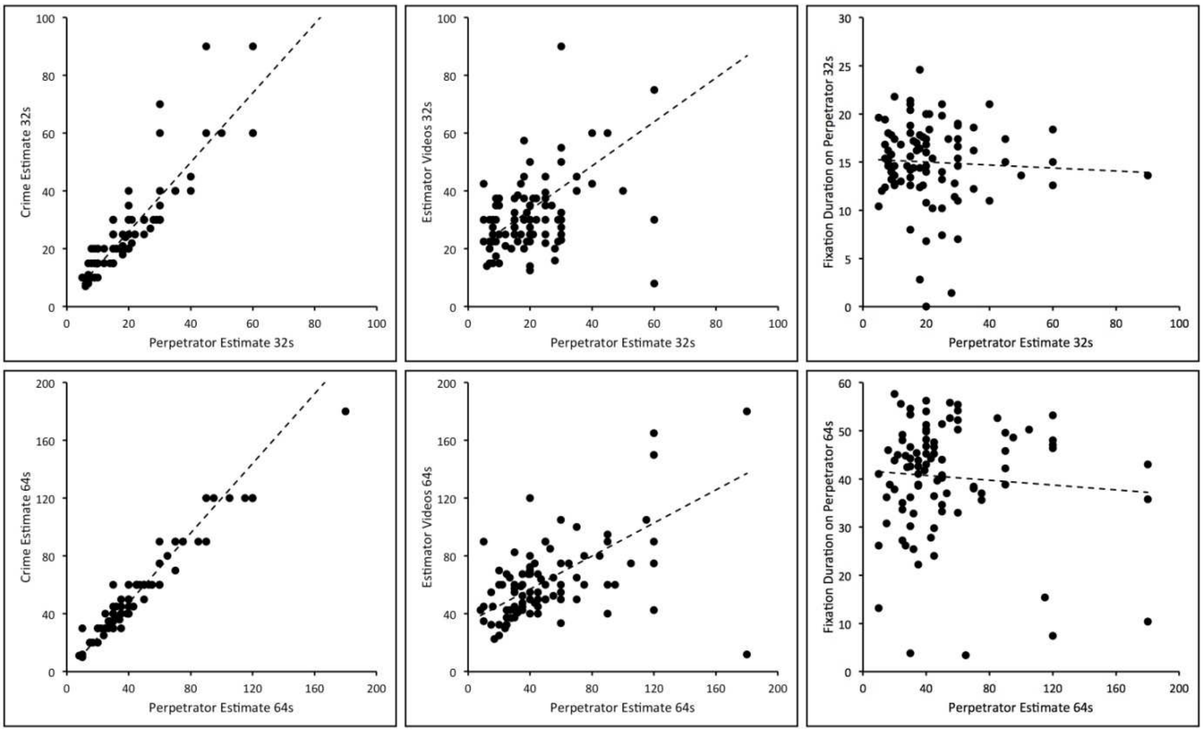

FIGURE 5. Content analysis of the four crime videos, charting the visibility of the perpetrators' bodies, heads and faces.

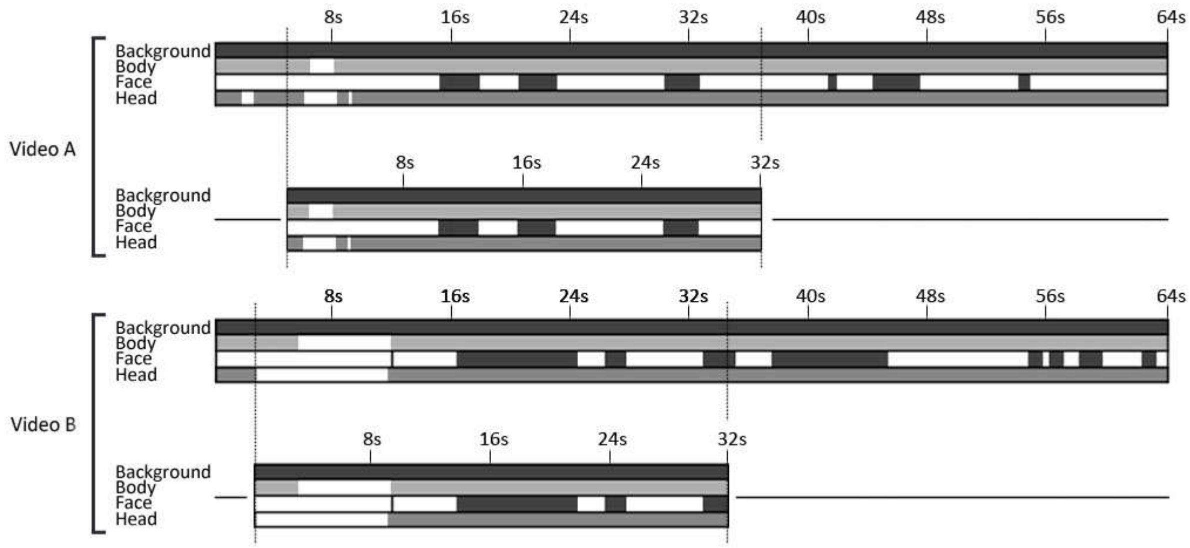

FIGURE 6. The percentage fixations, averaged across observers, on the perpetrators' faces in the four crime videos. The on- and offset of the data peaks corresponds directly to the time windows in which the perpetrators' faces were visible. Grey insets in the graphs for the long crime videos (right column) indicate the segments corresponding to the short crime videos (left column).