A multinomial analysis of the cognitive processes underlying eyewitness responses to lineups: Effects of eyewitness age, instructions on response time and lineup position

Inaugural-Dissertation

zur Erlangung des Doktorgrades
der Mathematisch-Naturwissenschaftlichen Fakultät
der Heinrich-Heine-Universität Düsseldorf

vorgelegt von

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Düsseldorf, 29. Juli 2025

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Gedruckt mit der Genehmigung der
Mathematisch-Naturwissenschaftlichen Fakultät der
Heinrich-Heine-Universität Düsseldorf

Berichterstatter:
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Tag der mündlichen Prüfung: 27.10.2025

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Abstract

Just as eyewitness testimony in police lineups can provide key evidence to convict culprits, false identifications of innocent suspects can have dramatic consequences. It is thus of utmost importance to understand the variables that affect eyewitness responses to lineups, because this information may help to better estimate the validity of eyewitness responses to lineups and to construct better lineups. In the present dissertation, the effects of three variables on the cognitive processes underlying eyewitness responses to lineups were assessed with the two-high threshold eyewitness identification model. A reanalysis of published data and Experiment 1 were conducted to examine the effects of the estimator variable of eyewitness age. To assess age-related differences in the cognitive processes underlying eyewitness responses to lineups, younger adults were compared to two groups of older adults. The probability of culprit-presence detection decreased significantly with age, while the probability of guessing-based selection increased significantly. Descriptive differences in the probability of culprit-absence detection did not always reach statistical significance. In Experiment 2, it was investigated whether culprit-presence detection can be improved by treating response time as a system variable and by instructing participants to respond fast rather than slowly. The model-based analyses revealed that instructions to respond fast rather than slowly did not affect the probability of culprit-presence detection. However, the probability of guessing-based selection was significantly increased when participants were instructed to respond fast rather than slowly. Lastly, in Experiments 3a and 3b, position effects were assessed in simultaneous and sequential lineups. The results of both experiments were largely consistent: There were no position effects on the probability of culprit-presence detection. However, the probability of guessing-based selection was significantly higher for the lineup member presented in Position 1 than for all other lineup members. Together, the present findings not only underline the usefulness of the two-high threshold eyewitness identification model for eyewitness research but also offer important insights into three different variables that affect the cognitive processes underlying eyewitness responses to lineups. Moreover, the present findings constitute starting points for future research aiming to find ways to improve police lineups.

Introduction

Eyewitness testimony in police lineups has long been recognized as a critical component in police investigations and as substantial evidence in court (e.g., Wells, 1993; Wells et al., 1998). In police lineups, a suspect is presented to an eyewitness of a crime along with fillers who are known to be innocent (Wells et al., 2020). The eyewitness is then tasked with identifying the culprit if present or alternatively indicating that the culprit is not among the presented individuals (Wells & Luus, 1990). If eyewitnesses identify a guilty suspect in a lineup, this information can contribute to the conviction of a culprit and thus aid the criminal justice system. However, if eyewitnesses select an innocent suspect in a lineup, this person is falsely incriminated and at worst wrongfully convicted. Data obtained by the Innocence Project indicate the consequences false identifications can have, not only in incidence but also in severity (Innocence Project, 2020). Out of over 375 individuals exonerated with the help of the Innocence Project between 1989 and 2020, 69 % had been misidentified by eyewitnesses. On average, the individuals exonerated by the Innocence Project had spent 14 years incarcerated, with some even facing death sentences.

To improve the validity of eyewitness testimony, researchers have spent decades investigating variables that affect eyewitness responses to lineups (Wells et al., 2020). Some of those variables lie outside the control of the criminal justice system, but can help in estimating the validity of eyewitness responses to lineups (Wells, 1978). They are called estimator variables. For instance, it has been shown that the extent and quality of the view of the culprit during the crime affect the likelihood that eyewitnesses will correctly identify the culprit in a later lineup: When eyewitnesses have more time to see the culprit, they are more likely to later identify them if present in a lineup and to reject the lineup if the culprit is not present compared to when they have less time to see the culprit (Memon et al., 2003). Additionally, eyewitnesses who see the culprit from a closer distance are more likely to correctly identify them in a lineup or to reject the lineup when the culprit is not present than eyewitnesses who see the culprit from a larger distance (Nyman et al., 2023). While these variables may aid police officers or legal personnel in determining the validity of eyewitness responses to lineups, they cannot be manipulated to improve eyewitness testimony. Other variables, called system variables, are under the control of the criminal justice system and can be adapted to improve eyewitness testimony (Wells, 1978). These system variables include, for instance, the instructions provided before lineup presentation—with unbiased instructions reducing the rates of innocent-suspect identifications compared to biased instructions (Lampinen et al., 2019)—and the delay between the crime and the presentation of the lineup (Cutler et al., 1986; Lin et al., 2019).

Researchers have used different ways to measure the validity of eyewitness responses to lineups to arrive at conclusions regarding estimator and system variables. A straightforward approach is to simply assess the observable responses eyewitnesses give to lineups. Researchers have inferred the effects of various variables on eyewitness responses to lineups from these observable response rates (e.g., Memon & Gabbert, 2003a; Palmer et al., 2017; Sporer, 1993). However, it is often not possible to draw finite conclusions based on raw response rates. For instance, consider the aforementioned variable of the delay between the crime and the lineup. While some studies have shown that the rate of culprit identifications decreases with increasing delay (Lin et al., 2019; Shepard, 1983), others have shown no effect of crime-lineup delay on culprit identifications (Egan et al., 1977; Wetmore et al., 2015). While these findings may indicate that the cognitive process of culprit-presence detection is unaffected by delay, they may also be the result of a decline in culprit-presence detection, which is compensated by a coinciding increase in guessing-based selection. Based on the observable responses alone, it is not possible to precisely determine which cognitive processes are affected by crime-lineup delays. However, such information would be crucial for the improvement of police lineups. A decline in memory might be met with efforts to help eyewitnesses remember the incident, perhaps via context reinstatement (Cutler et al., 1987; Wong & Read, 2011), whereas an increase in guessing-based selection might be attenuated by specific instructions not to guess. Thus, understanding the full picture of eyewitness responses to lineups is not just of theoretical but also of practical interest.

Other measures commonly used to investigate lineup-related research questions are the Diagnosticity Ratio (e.g., Carlson et al., 2008; Sporer, 1992; Wells & Lindsay, 1980) and Receiver Operating Characteristics (ROC) analyses (e.g., Colloff et al., 2017; Mickes et al., 2012; Wilson et al., 2019). While both may serve their intended purpose—the Diagnosticity Ratio indicates the probability that a selection from a lineup is correct (Wells & Lindsay, 1980) and ROC analyses indicate how well eyewitnesses can discriminate between culprits and innocent suspects (Mickes et al., 2012)—they are of limited use when the aim is to comprehend the variables that influence eyewitness responses to lineups. First, neither measure was developed specifically to encompass the complete range of responses possible in lineups. As a consequence, only some lineup responses, such as culprit identifications, innocent-suspect identifications and false and correct lineup rejections, are considered, and others, such as filler identifications, are disregarded. Therefore, potentially important information is neglected when using the Diagnosticity Ratio or ROC analyses. Second, both the Diagnosticity Ratio and ROC analyses only yield one metric. In consequence, researchers have had to resort to additional measures to assess important factors such as the eyewitnesses' inclination to select a lineup member (e.g., Dobolyi & Dodson, 2013; Horry et al., 2012) or lineup fairness (e.g., Lee et al., 2022; Mansour et al., 2017). Finally, neither measure has been experimentally validated, and it therefore remains unclear whether these measures sensitively measure what they are designated to measure.

In clear contrast, the two-high threshold eyewitness identification model (Menne et al., 2022; Winter et al., 2022) is not constrained by the aforementioned limitations. It incorporates all six possible responses to lineups: culprit identifications, innocent-suspect identifications, false and correct rejections and filler identifications in culprit-present and culprit-absent lineups. Based on these six data categories, the probabilities of four cognitive processes underlying the observable responses to lineups are determined. The two-high threshold eyewitness identification model is a multinomial processing tree model. Multinomial processing tree models are commonly used in cognitive psychology to separately and concurrently measure different cognitive processes underlying the observable behavior (Batchelder & Riefer, 1999; Erdfelder et al., 2009; Riefer & Batchelder, 1988).

In the two-high threshold eyewitness identification model, the probabilities of four cognitive processes are represented by the model parameters, which are defined by the model equations. Two of the cognitive processes are detection-based, culprit-presence detection and culprit-absence detection, and two are non-detection-based, biased suspect selection and guessing-based selection. An illustration of the two-high threshold eyewitness identification model in form of two processing trees is displayed in Figure 1. The two trees represent the two types of lineups that may be presented: culprit-present lineups with a guilty suspect and culprit-absent lineups with an innocent suspect. In a culprit-present lineup, the eyewitness detects the presence of the culprit with probability dP, in which case the guilty suspect is correctly identified. If the eyewitness fails to detect the culprit's presence with the complementary probability $1 - dP$, the two non-detection-based processes determine the eyewitness's response. If the culprit's photograph in some way stands out from the filler photographs in an unfair lineup and the eyewitness notices this, biased suspect selection occurs with the conditional probability $b > 0$. If biased suspect selection does not occur, with the complementary probability $1 - b$, the eyewitness may select a lineup member based on guessing. Guessing-based selection occurs with the conditional probability g and is followed by random sampling among the lineup members. In this case, the suspect is sampled with the same probability as any of the fillers, which is determined by the lineup size. In a six-person lineup, the probability that the culprit is selected by random sampling is 1/6. With the complementary probability 5/6, one of the fillers is selected by random sampling. If guessing-based selection does not occur, with the complementary probability $1 - g$, the lineup is rejected.

In a culprit-absent lineup, the absence of the culprit is detected with probability dA. In this case, the eyewitness correctly rejects the lineup. When the eyewitness does not detect the culprit's absence with the complementary probability $1 - dA$, the same two non-detection-based processes as in culprit-present lineups determine their response. These non-detection-based processes are assumed to be the same in culprit-present and culprit-absent lineups, because the eyewitness is in the same state of uncertainty regardless of whether they have not detected the presence or the absence of the culprit. In this state of uncertainty, the eyewitness cannot distinguish between culprit-present and culprit-absent lineups. However, unlike in culprit-present lineups, in culprit-absent lineups the selection of the suspect based on the non-detection-based processes leads to the selection of the innocent suspect in lieu of the culprit.

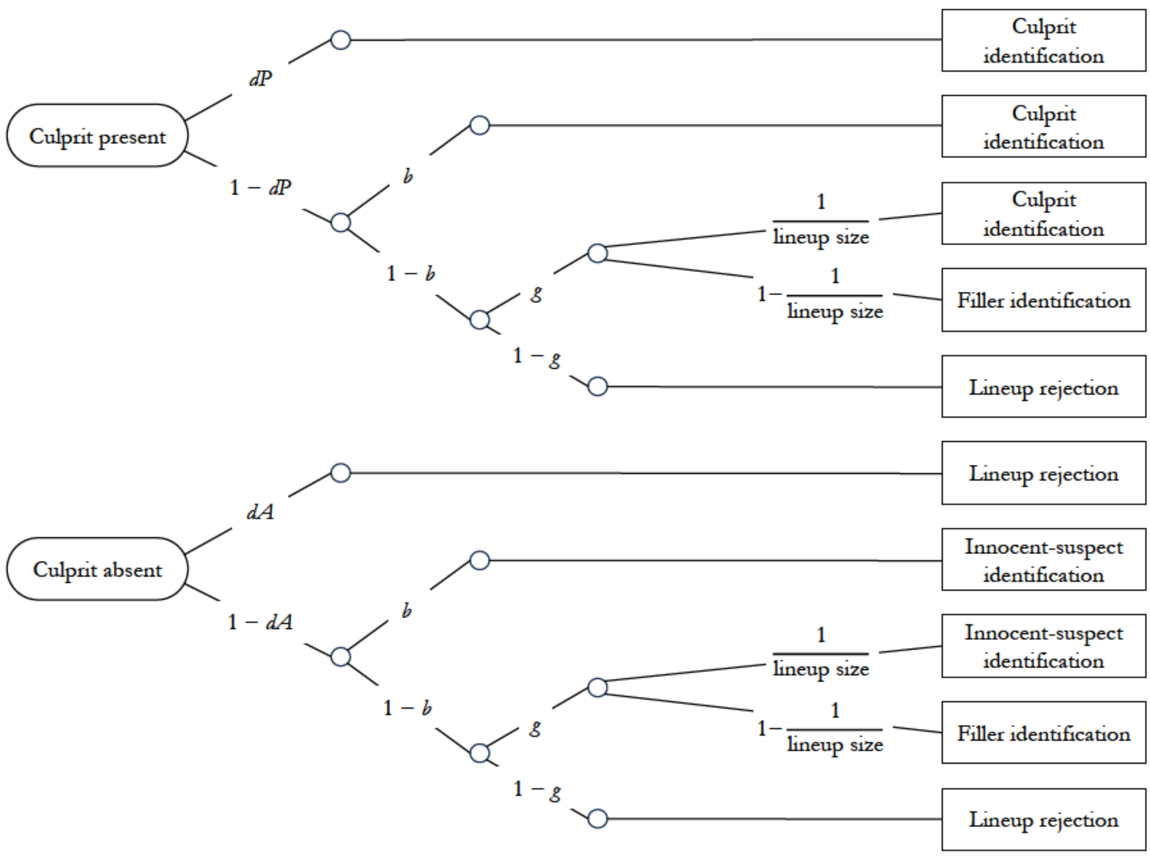

Figure 1. The two-high threshold eyewitness identification model illustrated in the form of processing trees. The ovals on the left represent the types of lineups presented to the eyewitnesses: culprit-present lineups and culprit-absent lineups. The rectangles on the right represent the observable response categories. The letters along the branches of the processing trees represent the probabilities of the cognitive processes underlying eyewitness responses to lineups (dP: culprit-presence detection; dA: culprit-absence detection; b: biased suspect selection; g: guessing-based selection). Guessing-based selection results in the selection of the (guilty or innocent) suspect with the sampling probability that is given by the reciprocal of the lineup size.

The two-high threshold eyewitness identification model has undergone intense validation. The findings of a series of designated validation experiments showed that the model parameters sensitively capture the cognitive processes they were designated to measure (Winter et al., 2022). Additionally, a series of reanalyses of published data from other laboratories using different procedures and stimulus sets provided evidence supporting the validity of the model parameters (Menne et al., 2022). After its validation, the model has been successfully used to address a variety of research questions (Bell et al., 2024; Menne et al., 2025; Menne et al., 2023a, 2023b; Therre et al., 2024; Winter et al., 2023) for example regarding the effects of the previously discussed crime-lineup delays: Therre et al. (2025) showed that the probability of culprit-presence detection decreases with an increasing crime-lineup delay, while the probability of guessing-based selection is unaffected.

In the present dissertation, the two-high threshold eyewitness identification model was used to address three other important estimator and system variables, namely age-related differences (Reanalysis and Experiment 1), the effects of instructions to respond fast rather than slowly to lineups (Experiment 2) and position effects (Experiments 3a and 3b) on the cognitive processes underlying eyewitness responses to lineups.

Age-related differences

Like many other cognitive capabilities, memory functions are subject to change in old age (e.g., Borella et al., 2007; Salthouse, 2004; Schnitzspahn & Kliegel, 2009). In police lineups, for which memory for the culprit is critical, the decline of memory abilities may have serious implications. Past research has established eyewitness age as an estimator variable and indicated that, compared to younger adults, older adults are less likely to correctly identify a culprit and, instead, are more likely to falsely select an innocent suspect or a filler (for meta-analyses, see Erickson et al., 2016; Fitzgerald & Price, 2015).

These age-related differences in the observable responses are likely indicative of changes at the level of the cognitive processes underlying eyewitness responses to lineups. The reduced rates of correct culprit identifications (Colloff et al., 2017; Havard & Memon, 2009; Humphries et al., 2024; Memon & Gabbert, 2003b; Rose et al., 2005; Wilcock et al., 2007; Wright & Stroud, 2002; Wylie et al., 2015), albeit not always reported (Key et al., 2015; Memon & Gabbert, 2003a; Nyman et al., 2023; Wilcock & Bull, 2010), might stem from a reduced probability of culprit-presence detection in older adults compared to younger adults. The reduced rates of lineup rejections (Erickson et al., 2016; Havard & Memon, 2009; Memon & Gabbert, 2003a; Pica & Pozzulo, 2018; Rose et al., 2005) and increased rates of innocent-suspect and filler identifications (Memon & Gabbert, 2003b; Pica & Pozzulo, 2018; Searcy et al., 1999; Wilcock & Bull, 2010; Wilcock et al., 2007) in older adults compared to younger adults might indicate a parallel decline in the probability of culprit-absence detection. However, the observed response pattern is ambiguous to interpret: An increased probability of guessing-based selection in older adults compared to younger adults might also result in fewer lineup rejections and increased rates of innocent-suspect and filler identifications. Thus, age-related differences in observable lineup responses might reflect both age-related differences in memory and an increased inclination to make a guessing-based selection in older adults. An increase in guessing-based selection could be due to an increased desire to 'help' the investigation or to compensate for their reduced memory, a common phenomenon in individuals with weak memory (e.g., Bayen & Kuhlmann, 2011; Ehrenberg & Klauer, 2005; Küppers & Bayen, 2014). Depending on which processes contribute to age-related differences in eyewitness responses to lineups, different methods specifically targeting the affected processes could improve the testimony of older adults. To obtain this information, the two-high threshold eyewitness identification model was used to independently measure age-related differences in the cognitive processes underlying eyewitness responses to lineups.

Research on age-related differences in lineups has typically included one group of younger adults which was compared to a single group of older adults (Havard & Memon, 2009; Humphries et al., 2024; Memon & Gabbert, 2003a, 2003b; Memon et al., 2003; Nyman et al., 2023; Pica & Pozzulo, 2018; Rose et al., 2005; Searcy et al., 1999; Wilcock & Bull, 2010; Wilcock et al., 2007; Wright & Stroud, 2002; Wylie et al., 2015; for an exception, see Scogin et al., 1994). However, as the distinction between young–old and old–old adults has yielded valuable results in research on cognitive aging (e.g., Aslan & Bäuml, 2013; Borella et al., 2007; Davis et al., 2003; Henry et al., 2015; Schmitter-Edgecombe & Simpson, 2001; Schnitzspahn & Kliegel, 2009), this distinction was included in the present research. First, in a reanalysis of previously published data, young to middle-aged adults were compared to young–old and old–old adults. Second, in Experiment 1 young adults were compared to young–old and old–old adults.

Reanalysis

In a first step, data from an experiment conducted for a different purpose (Mayer et al., 2024, Experiment 2) were reanalyzed (for details, see Mayer, Bell, Menne, Therre, et al., 2025). This specific dataset was selected because it comprised a large number of participants with a wide age range. Participants aged 18 to 59 were categorized as young to middle-aged adults (n = 1,452), participants aged 60 to 74 as young–old adults (n = 992), and participants aged 75 years or older as old–old adults (n = 137), based on previous categorizations of young–old adults and old–old adults (e.g., Aslan & Bäuml, 2013; Borella et al., 2007; Lamont et al., 2005; Schnitzspahn & Kliegel, 2009; Wright & Holliday, 2007).

All participants viewed one of two parallel staged-crime videos. In the staged-crime videos, four soccer fans verbally and physically attacked a fan of a rivaling soccer club. Both videos showed the same plot and actions but differed in the actors portraying the culprits. Subsequently, the participants saw four lineups, each containing one suspect and five fillers. Two of the lineups were culprit-present lineups and contained one of the aggressive soccer fans from the video the participants had seen. The other two lineups were culprit-absent lineups and did not contain any of the aggressive soccer fans from the video the participants had seen. Instead, they contained an innocent suspect from the parallel staged-crime video. The assignment of the four lineups as either culprit-present or culprit-absent, along with their order of presentation, was randomized. The lineups were presented in a sequential format, meaning that the six lineup members were shown one at a time in a randomized order. The participants had to indicate for each lineup member whether or not he was one of the culprits. In case the participants selected more than one person, the last selection was counted (Bell et al., 2024; Menne et al., 2023a, 2023b; Therre et al., 2024; Winter et al., 2022; different from Mayer et al., 2024). If none of the lineup members were selected, the lineup was classified as rejected.

The model-based analyses showed that the probability of culprit-presence detection decreased with age. The probability of culprit-presence detection was significantly higher in young to middle-aged adults than in young–old adults and significantly higher in young–old adults than in old–old adults. Descriptively, the probability of culprit-absence detection decreased as well, however, only the comparison between young to middle-aged adults and young–old adults reached statistical significance, whereas the comparison between young–old adults and old–old adults did not. The probability of guessing-based selection increased with age. The probability of guessing-based selection was significantly lower in young to middle-aged adults than in young–old adults and significantly lower in young–old adults than in old–old adults. The results thus indicate that the contribution of detection-based processes, namely culprit-presence and culprit-absence detection, to lineup responses decreases with age, while the contribution of guessing-based selection increases.

Given that the dataset reanalyzed here was not collected for the purpose of examining age-related differences, the number of participants in the different age groups differed substantially, affecting the statistical sensitivity of the conducted analyses. To assess the robustness and replicability of the findings, Experiment 1 with balanced age groups was conducted.

Experiment 1

In Experiment 1, the same materials and procedure as in the reanalyzed experiment were used (for details, see Mayer, Bell, Menne, Therre, et al., 2025). However, instead of a group of young to middle-aged adults, a group of young adults ($n = 510$) was compared to young–old adults ($n = 502$) and old–old adults ($n = 501$). As in multiple other studies assessing age-related differences in lineups (e.g., Havard & Memon, 2009; Humphries et al., 2024; Scogin et al., 1994; Wilcock & Bull, 2010), the young adults were between 18 and 35 years old. The categorization of young–old adults and old–old adults was the same as in the reanalysis. All groups contained approximately the same number of participants.

The results of Experiment 1 were largely consistent with those of the reanalysis. The probability of culprit-presence detection decreased with age and was significantly higher in young adults than in young–old adults and significantly higher in young–old adults than in old–old adults. Descriptively, the probability of culprit-absence detection decreased with age, but none of the comparisons was statistically significant. The probability of guessing-based selection increased with age and was significantly lower in young adults than in young–old adults and significantly lower in young–old adults than in old–old adults.

Discussion

For a comprehensive assessment of age-related differences in the cognitive processes underlying eyewitness responses to lineups, a reanalysis and Experiment 1 were conducted. Overall, the results of the reanalysis and of Experiment 1 are consistent and lead to clear conclusions. While the probability of culprit-presence detection decreases with age, the probability of guessing-based selection increases. Age-related differences in the probability of culprit-absence detection were not reliably found and, if present, might be very small and only detectable in highly sensitive analyses.

Altogether, the results of the reanalysis and Experiment 1 show notable age-related differences in the cognitive processes underlying eyewitness responses to lineups and align well with previous literature: The decreased probabilities of culprit-presence detection could lead to the previously reported lower rates of correct culprit identifications (Colloff et al., 2017; Havard & Memon, 2009; Humphries et al., 2024; Memon & Gabbert, 2003b; Rose et al., 2005; Wilcock et al., 2007; Wright & Stroud, 2002; Wylie et al., 2015), and the increased probabilities of guessing-based selection could contribute to lower rates of lineup rejections and increased rates of innocent-suspect and filler identifications in older adults compared to younger adults (Erickson et al., 2016;

Havard & Memon, 2009; Memon & Gabbert, 2003a, 2003b; Pica & Pozzulo, 2018; Rose et al., 2005; Searcy et al., 1999; Wilcock & Bull, 2010; Wilcock et al., 2007).

The present results also clearly demonstrate the advantages of the two-high threshold eyewitness identification model for lineup research. At the level of observable responses, it is not possible to determine whether the increase in innocent-suspect and filler identifications in older adults compared to younger adults (Memon & Gabbert, 2003b; Pica & Pozzulo, 2018; Searcy et al., 1999; Wilcock & Bull, 2010; Wilcock et al., 2007) results from a memory decline, namely from reduced culprit-absence detection, or from an increased inclination to select a lineup member based on guessing. In order to assess and to improve the validity of testimony by older adults, however, this is crucial information. Based on the present analyses, it is reasonable to conclude that these observable differences in the rates of innocent-suspect and filler identifications are mostly due to a higher probability of guessing-based selection in older adults compared to younger adults. Furthermore, the present results also underscore the importance of distinguishing between culprit-presence detection and culprit-absence detection. Otherwise, the fact that age-related differences only robustly manifest in culprit-presence detection but not in culprit-absence detection would have gone unnoticed. Dividing the older adults into young–old adults and old–old adults also revealed notable differences in the probabilities of culprit-presence detection and guessing-based selection between these groups that would have otherwise been missed.

To conclude, the research reported here shows pronounced age-related differences, specifically a shift from memory-based detection to guessing-based selection in older adults compared to younger adults. These changes pose significant challenges for the validity of lineup responses from older adults, which should be considered in police practice. Additionally, the present results offer starting points for future research to investigate ways to improve the validity of the testimony of older adults. For instance, in future studies researchers could assess how to attenuate the decline in culprit-presence detection. For instance, it has been shown that context reinstatement improves free recall in older adults even though it is not clear whether these findings generalize to recognition in lineups (Koutstaal et al., 1998). Moreover, it should be investigated whether the increase in guessing-based selection can be reduced via instructions that selectively discourage guessing (Therre et al., 2024; Winter et al., 2022). While the reanalysis and Experiment 1 address age as an estimator variable, in Experiment 2, response time, which is typically also seen as an estimator variable, was investigated for its potential as a system variable.

Response time

In addition to age, another well-known estimator variable is the time it takes an eyewitness to select someone from a lineup. Past research has shown that fast selections are more likely to be correct than slow selections (Brewer et al., 2006; Dunning & Perretta, 2002; Seale-Carlisle et al., 2019; Smith et al., 2001). Additionally, correct identifications of the culprit are made faster than incorrect identifications of the innocent suspect or a filler (Brewer et al., 2006; Bruer & Pozzulo, 2014; Flowe & Cottrell, 2011; Kneller & Harvey, 2016; Kneller et al., 2001; Price & Fitzgerald, 2024; Ross et al., 2007; Sauerland & Sporer, 2007, 2009; Sporer, 1992; Sporer, 1993; Weber et al., 2004). No such relationship has been found for lineup rejections (Dodson & Dobolyi, 2016; Flowe & Cottrell, 2011; Kneller & Harvey, 2016; Sauerland & Sporer, 2007, 2009; Smith et al., 2001; Sporer, 1992; Sporer, 1993; Weber et al., 2004).

As an estimator variable, eyewitnesses' response times in lineups have been discussed as a useful indicator of how likely a selection from a lineup is correct (Dunning & Perretta, 2002; Seale-Carlisle et al., 2019; Smith et al., 2001). However, theoretically, it is also possible to treat response time as a system variable and to manipulate it. Given the previous findings linking faster responses to a higher likelihood that a selection from a lineup is correct, the question arises whether encouraging fast responding might be beneficial. The aim of Experiment 2 was therefore to assess whether instructing eyewitnesses to respond fast rather than slowly improves culprit-presence detection. When responding fast, eyewitnesses might rely more strongly on mechanisms useful for culprit-presence detection, such as responding spontaneously (Dunning & Stern, 1994) or a "pop-out" effect (Brewer et al., 2000; Dunning & Perretta, 2002; Robinson et al., 1997) than when they are responding slowly. Still, it is also necessary to test for any adverse effects of such an instruction to respond fast rather than slowly. When responding fast, eyewitnesses might take less time to reflect and follow the instructions, including the instruction to reject the lineup when the culprit was not detected, than when responding slowly. This may, in turn, increase their probability of guessing-based selection. This idea is in line with the findings of Brewer et al. (2000), who reported that eyewitnesses who saw a lineup very briefly and had to respond right after seeing it were less likely to correctly identify the culprit and more likely to select a filler than eyewitnesses who saw the lineup for a longer duration before responding. To simultaneously assess the effects of instructing fast rather than slow responding on culprit-presence detection as well as on guessing-based selection, again, the two-high threshold eyewitness identification model was used.

Experiment 2

In Experiment 2, the same materials and procedure as in the reanalyzed experiment and Experiment 1 were used (for details, see Mayer, Bell, Menne, Lichtenhagen, et al., 2025). However, here the participants (N = 1503) were presented with simultaneous lineups, in which all six lineup members were simultaneously shown in a single line. In the fast-response condition, the participants were instructed to respond spontaneously and were reminded to do so before each lineup. Additionally, the participants could give their response after viewing the lineup for three seconds. In the slow-response condition, the participants were instructed and reminded to respond deliberatively. They viewed the lineup for 20 seconds before they could give their response. A comparison of the response times after lineup presentation showed that participants in the fast-response condition responded significantly faster than participants in the slow-response condition.

The model-based analyses showed no difference in the probability of culprit-presence detection between the fast-response condition and the slow-response condition. In contrast, the probability of guessing-based selection was significantly higher in the fast-response condition than in the slow-response condition.

Discussion

Based on the previously reported correlation between response time and the likelihood that a selection from a lineup is correct (Brewer et al., 2006; Dunning & Perretta, 2002; Seale-Carlisle et al., 2019; Smith et al., 2001), the aim of Experiment 2 was to assess whether instructing eyewitnesses to respond fast rather than slowly would increase the probability of culprit-presence detection. The model-based analyses showed that instructing fast rather than slow responding had no effect on culprit-presence detection. It is possible that culprit-presence detection, consistent with the previously found correlation, occurs within a short time of lineup presentation and after that cannot be impaired or improved by additional time before responding. The probability of guessing-based selection was higher in the fast-response condition than in the slow-response condition. This could be due to eyewitnesses taking less time to reflect on task instructions, such as the instruction to reject the lineup when the culprit was not detected, when responding fast than when responding slow.

The present findings are consistent with those of Brewer et al. (2000) who found that inducing fast response times decreased correct culprit identifications and increased filler identifications compared to inducing slow responses. Based on the present findings, instructing eyewitnesses to respond fast rather than slowly to lineups is not advisable. Besides yielding no beneficial effect on culprit-presence detection, such an encouragement could even be damaging by increasing guessing-based selection. Therefore, eyewitnesses should not be pressured to respond fast. Another relevant system variable that may influence eyewitness responses to lineups is the position of the suspect within a lineup, a factor that was systematically examined in Experiments 3a and 3b.

Position effects

An important system variable that police officers determine when compiling a lineup is the position of the suspect photograph within the lineup. While there is a scientific recommendation to randomize the suspect's position (Technical Working Group for Eyewitness Evidence, 1999), surveys and case analyses have shown that police practitioners prefer middle positions over edge positions (Flowe et al., 2018; Wogalter et al., 1993). Especially in sequential lineups, prosecutors are concerned about placing the suspect in Position 1 because defense lawyers could argue that the lineup was a showup if the suspect was selected in Position 1 (Wells et al., 2000; Wells et al., 2011; Wells et al., 2015). Consequently, researchers have sometimes avoided or recommended to avoid presenting the suspect in Position 1 as well (Hobson & Wilcock, 2011; Malpass et al., 2009; Wells et al., 2000; Wells et al., 2011; Wells et al., 2015).

Given this discrepancy between formal recommendation and applied practice, it is important to assess whether the concerns regarding Position 1 are justified. Previous studies on position effects in lineups have yielded mixed results. In simultaneous (Clark & Davey, 2005; Flowe & Ebbesen, 2007; Meisters et al., 2018) as well as in sequential lineups (Carlson & Carlson, 2014; Dobolyi & Dodson, 2013; Flowe et al., 2015; Lindsay & Wells, 1985; Sporer, 1993; Wells et al., 2015), some research has indicated no differences in culprit identification rates or the ability to discriminate between innocent suspects and culprits across lineup positions. However, there is also evidence indicating potential advantages of presenting the suspect in middle positions in simultaneous lineups (O'Connell & Synnott, 2009) or in early or late positions in sequential lineups (Carlson et al., 2008; Clark & Davey, 2005; Flowe & Ebbesen, 2007; Gronlund et al., 2012; Horry et al., 2012; Meisters et al., 2018; Neuschatz et al., 2016). Moreover, while some research suggests that eyewitnesses guess equally across all positions in simultaneous (Clark & Davey, 2005; Meisters et al., 2018; Wells et al., 2015) and sequential lineups (Dobolyi & Dodson, 2013; Lindsay & Wells, 1985; Sporer, 1993), other studies indicate that eyewitnesses are more likely to guess in earlier or middle positions in simultaneous (Gronlund et al., 2012; Nyman et al., 2020; Palmer et al., 2017) and sequential lineups (Dunn et al., 2022; Gronlund et al., 2012;

Nyman et al., 2020) or in later positions in sequential lineups (Horry et al., 2012; Meisters et al., 2018).

When interpreting these findings, several limitations common in previous research must be considered (Meisters et al., 2018). First, in many studies, the suspect's position was not allocated randomly and was often limited to a few positions, for instance, only to Position 2 and Position 5 (e.g., Carlson & Carlson, 2014; Carlson et al., 2016; Flowe et al., 2015; Horry et al., 2021). Furthermore, in many studies only small samples were recruited (e.g., Carlson et al., 2008; Clark & Davey, 2005; Dobolyi & Dodson, 2013), reducing the chance of detecting position effects, if they exist. Lastly, many previous studies have relied on observable response rates, the Diagnosticity Ratio or ROC analyses (e.g., Carlson et al., 2008; Carlson et al., 2019; Dunn et al., 2022; Meisters et al., 2018; O'Connell & Synnott, 2009; Palmer et al., 2017; Sporer, 1993; Wilson et al., 2019), which, as discussed above, have significant shortcomings.

The present research was specifically designed to circumvent these limitations. In Experiments 3a and 3b, large samples were collected, and the positions of all lineup members were completely randomized. Furthermore, for a comprehensive assessment, the two-high threshold eyewitness identification model was used to analyze position effects on the cognitive processes underlying eyewitness responses to lineups. The model-based analyses were focused on the processes of culprit-presence detection and guessing-based selection. While culprit-presence detection was conceptualized exactly as in the previous experiments, guessing-based selection was conceptualized slightly differently. In Experiments 3a and 3b, the probability of guessing-based selection in a given position referred specifically to the probability that the lineup member in this position was selected based on guessing. In Experiment 3a, position effects in simultaneous lineups were examined, and in Experiment 3b, position effects in sequential lineups were examined.

Experiment 3a

In Experiment 3a, the same materials and procedure as in Experiment 2 were used and the participants ($N = 2586$) were presented with simultaneous lineups (for details, see Mayer et al., 2024). As in all previous experiments, the positions of all six lineup members were randomized.

The model-based analyses showed that there were no position effects on culprit-presence detection. The participants exhibited the same probability of detecting the culprit's presence regardless of where he was presented. However, there were significant differences in the probability of guessing-based selection across the positions. Therefore, each position was compared to each of the other positions. These analyses showed that the probability of guessing-based selection was significantly higher in Position 1 than in all other positions. There were no significant differences between any of the other positions.

Experiment 3b

In Experiment 3b, the same materials and procedure as in Experiment 3a were used. However, as in the reanalyzed experiment and Experiment 1, the participants (N = 2581) were presented with sequential lineups (for details, see Mayer et al., 2024). In sequential lineups, eyewitnesses may select more than one lineup member. In this case, researchers typically include the participants' first or last selection in their analyses (Bell et al., 2024; Carlson et al., 2016; Carlson & Gronlund, 2011; Gronlund et al., 2012; Menne et al., 2023a, 2023b; Mickes et al., 2012; Therre et al., 2024; Winter et al., 2022). However, in an analysis of position effects, any decision to count the first selection would skew the results (Horry et al., 2021), as would the decision to count the last selection. Counting the first selection would artificially inflate the number of counted selections in earlier positions, while counting the last selection would inflate the number of counted selections in later positions. Furthermore, the focus of the present research was to learn about the cognitive processes underlying eyewitness responses to lineups and not about the consequences of decisions regarding data analyses. Therefore, only data from lineups with at most one selection were included in the model-based analyses.

The results were largely consistent with those of Experiment 3a: There were no position effects on culprit-presence detection. The participants exhibited the same probability to detect the culprit's presence, regardless of where he was presented. Again, there were significant differences in the probability of guessing-based selection across the positions. When each position was compared to each of the other positions, the probability of guessing-based selection was significantly higher in Position 1 than in all other positions. Except for a significant difference between Position 2 and Position 6, there were no significant differences between any of the other positions.

Discussion

Experiments 3a and 3b were conducted to assess whether the concerns of researchers and practitioners regarding Position 1 (Hobson & Wilcock, 2011; Malpass et al., 2009; Wells et al., 2000; Wells et al., 2011; Wells et al., 2015) are justified. To this end, the two-high threshold eyewitness identification model was used to analyze position effects on the cognitive processes underlying eyewitness responses to lineups. The results of both experiments were largely consistent: In both simultaneous and sequential lineups, there were no position effects on culprit-presence detection. The probability that the participants detected the presence of the culprit in the lineup did not differ across the positions. These results are consistent with previous studies in which no differences in culprit-identification rates and the ability to discriminate between guilty and innocent suspects across lineup positions were reported (Carlson & Carlson, 2014; Clark & Davey, 2005; Dobolyi & Dodson, 2013; Flowe & Ebbesen, 2007; Flowe et al., 2015; Lindsay & Wells, 1985; Meisters et al., 2018; Sporer, 1993; Wells et al., 2015). Additionally, in both simultaneous and sequential lineups, the probability of guessing-based selection was increased in Position 1, a particularly salient position, compared to the other positions. These results align well with previous research reporting a greater tendency to make a selection in earlier positions than in later positions (Dunn et al., 2022; Gronlund et al., 2012; Nyman et al., 2020; Palmer et al., 2017).

At first glance, the present result pattern seems to warrant the existing reservations regarding placing the suspect in Position 1. However, according to the Technical Working Group for Eyewitness Evidence (1999), the suspect's position should be determined at random. Additionally, if the suspect was never placed in Position 1 and eyewitnesses came to know this, they would likely disregard any lineup member presented there completely. This could not only decrease the functional lineup size but could also possibly turn Position 2 into the new Position 1. Therefore, instead of avoiding Position 1, a more appropriate strategy may be to promote an even distribution of guessing-based selection across the lineup positions. For instance, eyewitnesses could be informed that the suspect's position was determined at random (Palmer et al., 2017). Alternatively, simultaneous lineups could be presented in array shapes without any especially salient positions, for instance in a circle (Palmer et al., 2017). Another goal could be to discourage guessing-based selections overall, for instance via specific instructions (Therre et al., 2024; Winter et al., 2022), which is generally beneficial because selections based on guessing hold no evidentiary value.

General discussion

In this dissertation, the effects of one estimator and two system variables on the cognitive processes underlying eyewitness responses to lineups were investigated. By applying the two-high threshold eyewitness identification model, it was possible to incorporate all observable lineup responses to simultaneously assess the effects on the different cognitive processes underlying eyewitness responses to lineups.

The reanalysis and Experiment 1 were conducted to assess the estimator variable of age. While some past research indicated that, compared to younger adults, older adults are less likely to correctly identify the culprit and more likely to falsely select an innocent suspect or a filler

(Colloff et al., 2017; Erickson et al., 2016; Havard & Memon, 2009; Humphries et al., 2024; Memon & Gabbert, 2003a, 2003b; Pica & Pozzulo, 2018; Rose et al., 2005; Searcy et al., 1999; Wilcock & Bull, 2010; Wilcock et al., 2007; Wright & Stroud, 2002; Wylie et al., 2015), these findings do not allow for conclusions regarding age-related differences in the cognitive processes underlying eyewitness responses to lineups. It remained unclear whether the increase in innocent-suspect and filler identifications resulted from a reduced probability of culprit-absence detection and thus a decrease in memory, or from an increased probability of guessing-based selection, possibly due to efforts to compensate for decreased memory or an increased motivation to 'help' the police. To further add to past research, the reanalysis and Experiment 1 included two older groups: a young–old group and an old–old group. This distinction is common in research on cognitive aging (e.g., Aslan & Bäuml, 2013; Borella et al., 2007; Davis et al., 2003; Henry et al., 2015; Schmitter-Edgecombe & Simpson, 2001; Schnitzspahn & Kliegel, 2009), but so far rare in research on police lineups (Havard & Memon, 2009; Humphries et al., 2024; Memon & Gabbert, 2003a, 2003b; Memon et al., 2003; Nyman et al., 2023; Pica & Pozzulo, 2018; Rose et al., 2005; Searcy et al., 1999; Wilcock & Bull, 2010; Wilcock et al., 2007; Wright & Stroud, 2002; Wylie et al., 2015; for an exception, see Scogin et al., 1994). The present results show an age-related decline in the probability of culprit-presence detection which is accompanied by an age-related increase in the probability of guessing-based selection. An age-related difference, namely a reduction, in the probability of culprit-absence detection manifested descriptively but did not reach statistical significance in all comparisons. The observable increase in innocent-suspect and filler identifications is thus mostly due to a higher probability of guessing-based selection in older adults compared to younger adults. These results, which are uniquely obtainable only with the two-high threshold eyewitness identification model, highlight challenges for the testimony of older adults and, at the same time, offer tangible insights for research aiming to find ways to improve the eyewitness testimony of older adults.

Experiment 2 was conducted to assess whether instructing eyewitnesses to respond fast rather than slowly influences culprit-presence detection and guessing-based selection. The time it takes eyewitnesses to respond is a well-known estimator variable: Eyewitnesses who select faster are more likely to pick the culprit and less likely to pick the innocent suspect or a filler than eyewitnesses who are slower to respond (Brewer et al., 2006; Dunning & Perretta, 2002; Seale-Carlisle et al., 2019; Smith et al., 2001). Based on this correlational evidence, in Experiment 2, it was investigated whether treating response time as a system variable and instructing participants to respond fast rather than slowly would improve culprit-presence detection. Furthermore, possible adverse effects of such instructions on guessing-based selection were assessed. The results showed no significant effect on the probability of culprit-presence detection. In contrast, the probability of guessing-based selection was increased when participants were instructed to respond fast rather than slowly. It is plausible that eyewitnesses detect the culprit's presence within a short time of lineup presentation, leaving the process unaffected by any additional time before responding. However, when instructed to respond fast rather than slowly, eyewitnesses might take less time to reflect on the instruction to reject the lineup when the culprit was not detected. This could cause the increased probability of guessing-based selection. In light of these results, it is not advisable to encourage eyewitnesses to respond fast rather than slowly.

Experiments 3a and 3b served to investigate the system variable of lineup position. While the formal recommendation is to randomize the suspect's position in a lineup (Technical Working Group for Eyewitness Evidence, 1999), practitioners and, in some cases, researchers avoid placing the suspect in Position 1 (Flowe et al., 2018; Hobson & Wilcock, 2011; Wells et al., 2011; Wells et al., 2015; Wogalter et al., 1993). Given the methodological limitations and mixed findings of previous research (e.g., Carlson & Carlson, 2014; Carlson et al., 2016; Carlson et al., 2008; Clark & Davey, 2005; Dobolyi & Dodson, 2013; Flowe et al., 2015; Horry et al., 2021; Meisters et al., 2018), position effects on the cognitive processes underlying eyewitness responses to lineups were assessed in two large-scale experiments, one featuring simultaneous and one featuring sequential lineups. The model-based analyses revealed no position effects on culprit-presence detection in either type of lineup. Participants displayed the same probability to detect the culprit's presence regardless of where he was presented. However, guessing-based selection differed significantly across positions. Participants were more likely to make a guessing-based selection of the lineup member presented in Position 1 than of the lineup members presented in other positions. Therefore, the present results support the concerns regarding Position 1.

Altogether, three important variables for eyewitness responses to lineups were addressed in the present dissertation. Understanding the effects of these variables is essential, given that eyewitness identifications are regarded highly as evidence in court (Wells et al., 1998), despite being prone to error (Wells et al., 2020). While correct identifications of culprits may support their prosecution, false identifications of innocent suspects may have dramatic consequences. Even though estimator variables, such as eyewitness age, are not under the direct influence of actors in the criminal justice system, understanding them is still highly valuable to evaluate the validity of eyewitness responses to lineups. Furthermore, in some cases, such as age-related differences, insight into these variables can guide adaptations to the lineup procedure for different circumstances. For instance, it may be beneficial to put more emphasis on discouraging guessing in older adults. Findings from research on system variables can contribute to creating lineups that support detection-based processes and minimize non-detection-based processes. Thereby, correct identifications of culprits are facilitated, while false innocent-suspect identifications are prevented. For instance, the present research shows that instructing eyewitnesses to respond fast rather than slowly should be avoided because it increases the probability of guessing-based selection.

The two-high threshold eyewitness identification model is especially valuable for addressing these questions because it offers information beyond the observable responses and, instead, enables a differentiated assessment of the effects of system and estimator variables on four different latent cognitive processes. Two of those processes are detection-based and thus desirable in lineups, while the other two are non-detection-based and thus undesirable. Alongside its extensive validation (Menne et al., 2022; Winter et al., 2022) and the inclusion of the full range of lineup responses, this distinction is an important strength of research using the two-high threshold eyewitness identification model. Based on the present model-based analyses, researchers can now assess specific methods to improve eyewitness responses to lineups by purposefully targeting the underlying cognitive processes. For instance, in future studies, it can be assessed whether the decrease in the probability of culprit-presence detection in older adults can be mitigated by specific methods, such as context-reinstatement, which has been shown to improve free recall in older adults even though it is not clear whether these findings generalize to recognition in lineups (Koutstaal et al., 1998). Similarly, it should be investigated whether the increase in the probability of guessing-based selection in older adults could be prevented by instructions that discourage guessing-based selection (Therre et al., 2024; Winter et al., 2022). If effective, these methods could be implemented in police practice to improve the validity of eyewitness testimony of older adults. Similarly, based on the present results, it could be assessed whether equal probabilities of guessing-based selection can be achieved for all lineup positions, for instance, by informing eyewitnesses that the suspect's position was determined at random or by using array shapes without particularly salient positions in simultaneous lineups (Palmer et al., 2017). Depending on the success of these methods, practitioners should be encouraged to follow the recommendation of randomizing the suspect's position.

In sum, the findings presented in this dissertation represent a significant contribution to the research efforts on eyewitness testimony in police lineups. They offer relevant insights for police practice as well as valuable direction for future research. Nevertheless, many other important estimator and system variables require further investigation, which is why continued research in this area remains crucial.

Conclusion

All in all, the present dissertation shows that the cognitive processes underlying eyewitness responses to lineups are affected by different estimator and system variables. Across one reanalysis and four experiments, it was shown that eyewitness age, instructions regarding fast or slow responding and lineup position significantly affect different cognitive processes underlying eyewitness responses to lineups. The present findings demonstrate the importance of continuously investigating lineup procedures, as such variables should be considered when constructing lineups. Furthermore, the present results highlight the substantial value of the two-high threshold eyewitness identification model. While results based on observable response rates remain ambiguous, the model helps to distinguish between detection-based processes, which are desirable for correct responses to lineups, and non-detection-based and therefore undesirable processes. The results at the level of the cognitive processes are particularly useful because they pinpoint which processes should be targeted to improve eyewitness responses to lineups. Thereby, the identification of effective methods to improve lineups in police practice is facilitated. In consequence, correct identifications of guilty culprits can be supported, while the risk of false identifications of innocent suspects is minimized.

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Published articles

Article 1

This article includes Experiments 3a and 3b.

Mayer, C., Bell, R., Menne, N. M., & Buchner, A. (2024). Lineup position affects guessing-based selection but not culprit-presence detection in simultaneous and sequential lineups. *Scientific Reports*, *14*, Article 27642. https://doi.org/10.1038/s41598-024-78936-9

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Lineup position affects guessing-based selection but not culprit-presence detection in simultaneous and sequential lineups

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The two-high threshold eyewitness identification model was applied to investigate the effects of lineup position on the latent cognitive processes underlying eyewitness responses in lineups. In two experiments with large sample sizes and random assignment of culprits and innocent suspects to all possible lineup positions, we examined how detection-based and non-detection-based processes vary across the positions of six-person photo lineups. Experiment 1 (*N* = 2586) served to investigate position effects in simultaneous lineups in which all photos were presented in a single row. Experiment 2 (*N* = 2581) was focused on sequential lineups. In both experiments, lineup position had no effect on the detection of the presence of the culprit. Guessing-based selection, in contrast, differed as a function of lineup position. Specifically, a lineup member placed in the first position in a lineup was significantly more likely to be selected based on guessing than lineup members placed in other positions. These results justify the practice of avoiding to place the suspect in the first position in a lineup, as this placement increases the suspect's chance of being selected based on guessing.

Keywords Position effects, Simultaneous lineups, Sequential lineups, Two-high threshold eyewitness identification model

Prompted by concerns that false eyewitness identifications can lead to wrongful convictions[1], researchers have investigated influences on eyewitness performance for decades[2–11]. In some cases, their insights have made their way into practice[12], and some of their findings are now included in the recommended procedures in different jurisdictions[2,13]. In other instances, it is unclear whether existing practice in applied contexts is corroborated by scientific research. Specifically, the placement of suspects in lineups sometimes conflicts with formal recommendations. On the one hand, the Technical Working Group for Eyewitness Evidence has recommended randomly selecting the suspect's position for each lineup[14]. On the other hand, practitioners often avoid placing the suspect in certain positions when they compile lineups. In a survey by Wogalter et al.[15], over 80 % of police officers reported usually placing the suspect in the middle of a lineup. Additionally, an analysis of case files showed that the suspect had been placed in Positions 2 to 5 in about 85 % of the cases, leaving only 15 % of the cases in which the suspect had been placed in Positions 1 or 6 combined[16]. In line with police practice, lineup researchers sometimes avoid placing the suspect in the first or last position in lineups as well[17]. Referring to sequential lineups in particular, researchers have expressed concerns with placing the suspect in the first position. For instance, Malpass et al.[18] have recommended that, in addition to randomizing positions, "the suspect should not be presented first in the sequence" (p. 4) to reduce the rate of false identifications. There are also reports that placing the suspect in the first position may give the defense opportunity to argue against the validity of the lineup procedure[2,19,20]. To illustrate, Wells et al.[2] write: "Valid concerns were raised (…) about a situation in which the suspect was placed in Position 1 (positioning is supposed to be random) and the eyewitness selects the suspect. The defense would argue that this was the equivalent of a showup (an identification procedure with only the suspect and no fillers)" (p. 595). In consequence, presenting the suspect in first position has been avoided in field studies[19,20]. Considering these widespread concerns about placing the suspect in the first position in a lineup, the question arises as to whether these concerns are in fact scientifically valid.

Researchers have employed various performance measures to investigate lineup-position effects, such as response rates[21–23], probative value[24,25] or ROC-based analysis of pAUCs[26–29], typically with the aim of determining in which position the guilt or innocence of a suspect can be best ascertained by a specific procedure

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such as the sequential lineup. A thorough review of the literature on possible lineup-position effects on eyewitness performance has shown that the empirical results are mixed and inconclusive[28]. A common limitation of many previous studies lies in the selective and non-random assignment of the lineup members to positions. For example, the suspect may have been placed in Positions 2 and 5, with no regard to Position 1. Furthermore, the interpretation of existing results is often complicated by small sample sizes, reducing the chances of finding a position effect if it exists.

In the present study, we examined lineup-position effects on the latent cognitive processes underlying eyewitness responses using large sample sizes and random assignment of culprits and innocent suspects to all lineup positions. To this end, the two-high threshold (2-HT) eyewitness identification model[30,31] was applied to the analysis of position effects. The model belongs to the general class of multinomial processing tree models which serve to estimate the probabilities of latent cognitive processes from behavioral data[32–34]. In memory research, these models have become popular due to their capacity to separate various types of memory processes from each other and from guessing processes[35–41]. To separately measure the cognitive processes underlying eyewitness responses, the 2-HT eyewitness identification model incorporates all observable response categories that can emerge in lineups: suspect identifications, filler identifications and lineup rejections in both culprit-present and culprit-absent lineups. Based on the frequencies of responses in these response categories, parameters are estimated that represent the detection of the presence of the culprit, the detection of the absence of the culprit, biased selection of the suspect and guessing-based selection of a lineup member. A crucial advantage of this measurement model is that its parameters have been rigorously validated, both in studies explicitly designed to test the model's validity[30] and in reanalyses of data from other laboratories[31]. Additionally, the model has already proven to be highly useful for investigating novel research questions about the latent processes underlying eyewitness responses[5,42–45].

An illustration of the 2-HT eyewitness identification model is displayed in Fig. 1. This model is a joint multinomial model[34] comprising two trees. The upper tree depicts the processes that may occur when the culprit is present in the lineup. The lower tree depicts the processes that may occur when the culprit is absent. Since the model is a joint multinomial model, data from both culprit-present and culprit-absent lineups are used to estimate all four parameters of the model[46].

In a culprit-present lineup, the presence of the culprit is detected with probability dP, resulting in a correct identification. If the presence of the culprit is not detected, which occurs with the complementary probability $1 - dP$, the eyewitness's responses are determined by non-detection-based processes. With the conditional

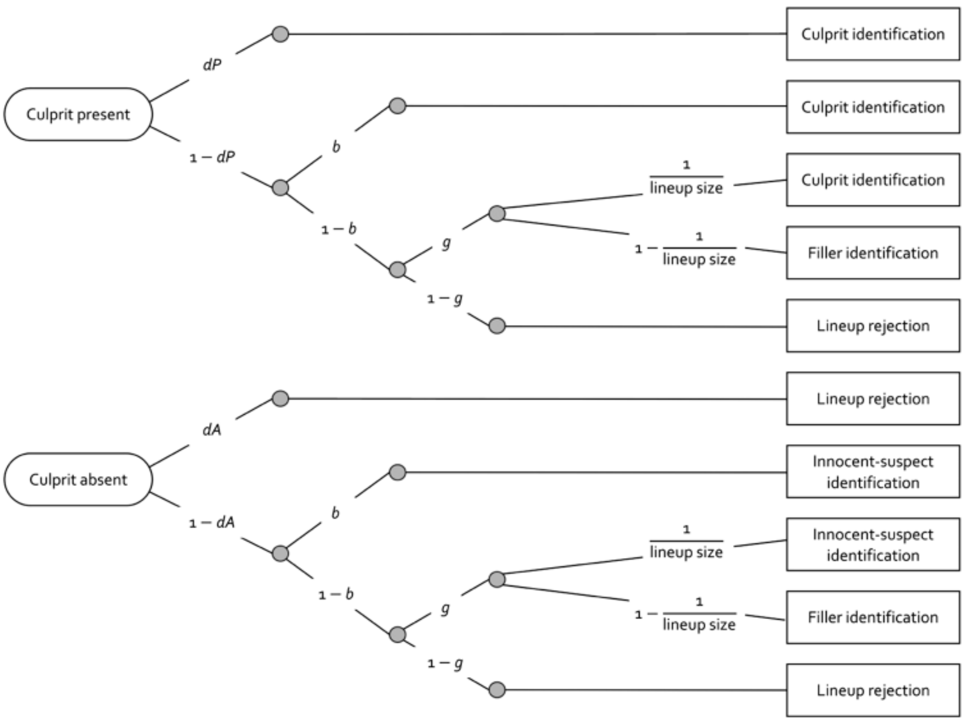

Figure 1. An illustration of the 2-HT eyewitness identification model in the form of processing trees. The ovals on the left represent the different types of lineups presented: culprit-present lineups and culprit-absent lineups. The rectangles on the right show the observable response categories. The letters attached to the branches connecting the ovals and rectangles represent the cognitive processes underlying eyewitness responses (dP: probability of detecting the presence of the culprit; b: probability of biased selection of the suspect; g: probability of guessing-based selection of a lineup member; dA: probability of detecting the absence of the culprit). Guessing-based selection results in the selection of the suspect with the sampling probability that is given by the reciprocal of the lineup size.

probability b, the eyewitness may select the suspect because the suspect stands out from the fillers; this may be the case in unfair lineups[30,31]. In case of no biased suspect selection, which occurs with the complementary probability $1 - b$, the eyewitness may select a lineup member based on guessing. Guessing-based selection occurs with the conditional probability g. In this case, the conditional probabilities of suspect and filler identifications depend upon the lineup size. With probability 1 *lineup size* (1 6 1 ÷ 6 in six-person lineups), the lineup member selected based on guessing is the suspect. With probability $1 - (1 \div \textit{lineup size})$, the lineup member selected based on guessing is a filler. In case of no guessing-based selection, which occurs with the complementary probability $1 - g$, the eyewitness may reject the lineup.

If the culprit is not present in the lineup, their absence is detected with probability dA, leading to a correct rejection of the lineup. If the absence of the culprit is not detected, which occurs with the complementary probability $1 - dA$, the same non-detection-based processes take place as in culprit-present lineups. These non-detection-based processes are the same in both culprit-present and culprit-absent lineups because, when neither the presence nor the absence of the culprit is detected, culprit-present and culprit-absent lineups appear the same to the eyewitness.

In previous applications of the 2-HT eyewitness identification model[5,42–45], the analyses were focused on data aggregated over lineup positions. Here, we applied the 2-HT eyewitness identification model to the examination of how lineup position affects the cognitive processes underlying eyewitness responses. Lineup-position effects were examined in simultaneous lineups in Experiment 1 and in sequential lineups in Experiment 2. Accordingly, the results of previous research regarding position effects in simultaneous and sequential lineups are discussed in the introductions to Experiments 1 and 2, respectively.

Experiment 1

Experiment 1 was designed to investigate the effects of lineup position on the detection-based and non-detection-based processes underlying eyewitness responses in simultaneous lineups. In simultaneous lineups, all lineup members—the suspect and the fillers—are presented at the same time[47]. The lineups used here consisted of six photos presented in a single row, with Position 1 referring to the leftmost position and Position 6 referring to the rightmost position.

The first aim of Experiment 1 was to test whether lineup position affects the detection of the presence of the culprit. For most previous studies it was reported that lineup position had no effect on the rate of culprit identifications or the ability to discriminate between culprits and innocent suspects in simultaneous lineups[6,28,48]. However, O'Connell and Synnott[22] reported better discriminability in middle positions which could come about if participants focused their attention more strongly on middle positions than on edge positions. Based on these findings, it is interesting to test whether culprit-presence detection is increased in middle positions of a lineup even though the results of most studies suggest that there should be no effect of lineup position on the detection of culprit presence in simultaneous lineups.

Another aim of Experiment 1 was to test whether lineup position affects guessing-based selection. For several previous studies it was reported that lineup position did not affect overall identification rates, rejection rates or the response criterion in simultaneous lineups[20,28,48]. However, there are also studies suggesting that people may be more likely to select lineup members based on guessing in earlier positions[21,49,50] or in middle positions[21]. In summary, there is thus some evidence in support of the concerns about placing the suspect in Position 1 in a lineup[2,19,20]. The purpose of the present experiments was to assess, using sensitive statistical tests based on large sample sizes, whether the reason for these concerns can be confirmed or not.

Method

Participants

Participants were recruited and compensated through the research panel of Bilendi GmbH (https://www.bilendi.de). Data for Experiments 1 and 2 were collected simultaneously in one wave for logistic and monetary reasons. Of the data files of the participants who filled out the socio-demographic questionnaire at the beginning of Experiment 1, a total of 443 were excluded because the participants either did not complete the experiment or revoked the consent to the use of their data, 149 were excluded because the participants saw the staged-crime video more than once and 51 were excluded because the participants failed the attention check (see Procedure section). The final sample included 2586 participants (1193 female, 1389 male, 4 diverse) with a mean age of 54 years ($SD = 16$). The sample was characterized by a diversified level of education: Secondary education had been completed by around 46 % of the participants, around 20 % of the participants also had obtained university entrance qualification and around 33 % also had obtained a university degree or a comparable qualification.

A sensitivity analysis conducted using G*Power[51] indicated that, with a sample size of $N = 2586$, four lineups per participant and $\alpha = \beta = 0.05$, it was possible to detect effects of lineup position on the model parameters as small as $w = 0.04$ in goodness-of-fit tests with $df = 5$ (comparison of all lineup positions simultaneously, see Results section).

Ethics statement

Experiments 1 and 2 are part of a series of experiments that were approved by the ethics committee of the Faculty of Mathematics and Natural Sciences at Heinrich Heine University Düsseldorf. Both experiments were conducted in accordance with the Declaration of Helsinki. In both experiments, participants gave informed consent prior to participation. Participants were informed that the experiments involved seeing a video depicting verbal and physical harassment. They were asked not to proceed with the experiment if they felt uncomfortable imagining to watch such a video. At the end of the experiments, participants were informed that the video showing the crime had been staged.

Materials

We used the same staged-crime videos, suspect photos, filler photos and lineup design as in previous experiments[5,30,42–45].

Staged-crime videos   Participants watched one of two staged-crime videos. In both videos, four culprits wearing fan clothing of the soccer club FC Bayern München harassed a victim wearing fan clothing of the soccer club Borussia Dortmund. All culprits were involved in the incident to a similar extent. By including four culprits, we were able to obtain four data points per participant and thereby increased the statistical sensitivity of our analyses. This procedure is ecologically valid as a notable share of real-world crimes includes multiple culprits[17,52,53]. Responding to multiple lineups after having witnessed a multiple-culprit crime seems to be harder than responding to a single lineup after having witnessed a single-culprit crime[54].

The videos showed the culprits coming upon the victim at a bus stop and initially making fun of him and insulting him. Then they started to take his belongings and tossed them around. They began to attack the victim physically, ultimately knocking him to the ground. They continued to verbally and physically abuse him until one of the culprits noticed another person approaching (not visible in the videos). Then the culprits fled, shouting loudly. Both videos followed the same plot and included the same actions in the same sequence and timing. The videos only differed in the actors playing the culprits and the victim. The actors were selected ensuring that the actor for each culprit in Video A resembled the actor for the corresponding culprit in Video B. The videos showed a clear and frontal view of all the culprits' faces. The culprits were visible for essentially the entire duration of the videos. Each video lasted for roughly 130 seconds and was shown at a resolution of 885×500 pixels.

Lineups   Participants were shown four lineups, one for each culprit in the staged-crime videos. Each lineup consisted of one suspect and five fillers. Culprit presence was manipulated using the crossed-lineup procedure[5,30,42–45]. In culprit-present lineups, the suspect was a culprit from the video that the participants had previously seen. In culprit-absent lineups, the suspect was a culprit from the video the participants had not seen. For example, if participants had seen Video A and the culprit-present lineups featured Culprits 1 and 3 from Video A, then the culprit-absent lineups featured innocent suspects that were Culprits 2 and 4 from Video B. The filler photos were obtained from the Center for Vital Longevity Face Database[55]. The photos showed white men between 18 and 29 years of age without any distinguishing marks such as scars or facial tattoos. The fillers were selected to resemble the culprits, who were white male young adults, in terms of body shape, hair color and hairstyle. All filler and suspect photos showed a frontal view of the face with a neutral facial expression. They were matched for lighting and face size and presented at a resolution of 142×214 pixels. The crossed-lineup procedure ensures that there are no systematic differences between culprits and innocent suspects but at the same time maintains ecological validity because, in police practice, the photo of the suspect, whose guilt or innocence is unknown, is often derived from a different source (e.g., a mug shot or social media) than the photos of the fillers (usually obtained from databases).

Procedure   The procedure followed the one described by Bell et al.[44], Menne et al.[5,42], Therre et al.[45] and Winter et al.[30,43]. The experiment was programmed and conducted online using SoSci Survey[56].

Participants were asked for their informed consent after having been informed that the experiment involved seeing a video depicting verbal and physical harassment. They were asked not to proceed if they felt uncomfortable imagining to watch such a video. Then, participants filled out the socio-demographic questionnaire and saw one of the two staged-crime videos described above. While watching the video, participants were unaware that they later would have to respond to lineups.

Which of the two videos was shown was determined at random. Participants started the video by clicking on a "Start" button. It was not possible to fast-forward, pause or replay the video. After the whole video had played, participants could continue to the next page which contained an attention-check question: Out of ten alternatives, participants had to correctly select "soccer fans" as the type of persons shown in the video. For participants who did not answer this question correctly, the experiment was terminated, and no further data were collected.

Next, the remaining participants received the lineup instructions. They were informed that they were about to see multiple lineups and were tasked with identifying the culprits from the video. Participants were told that the lineups might or might not contain a culprit and that it was as important to identify the culprit when he was present as it was to reject the lineup when the culprit was absent. Then, four lineups, one for each culprit in the video, were presented in a random order. Two of the lineups were randomly selected to be culprit-present lineups while the other two were culprit-absent lineups. As in studies by Clark and Davey[48] and by Meisters et al.[28], all photos of the lineup members were presented simultaneously in one single row, which is one possible format to present simultaneous lineups[13]. This format approximates the layout of in-person lineups[22] which are still present in guidelines in different jurisdictions[13]. Furthermore, this presentation format ensures that lineup position varies in only one dimension (i.e., lineup position varies horizontally), just like in sequential lineups where individual photos are presented one after another (i.e., lineup position varies temporally).

The positions of the lineup members within each of the four lineups were completely randomized. Beneath each of the six photos was a button labeled "Yes, was present" that could be used to identify a lineup member. Additionally, a button "No, none of these persons was present" was displayed next to the lineup. This button could be used to reject the lineup. Participants had to either identify a lineup member or reject the lineup before they could click the "Next" button to proceed. After the last lineup, participants were debriefed and thanked for their participation.

Results

Goodness-of-fit tests and parameter estimates were calculated using multiTree[57]. For data analysis, we needed six instances of the 2-HT eyewitness identification model depicted in Figure 1, one for each lineup position. The observed response frequencies that formed the basis of our analyses are reported in Table 1. The frequencies of culprit and innocent-suspect identifications refer to the number of culprits and innocent suspects that were identified in each lineup position in culprit-present and culprit-absent lineups, respectively. Similarly, the frequencies of filler identifications in culprit-present and culprit-absent lineups refer to the number of fillers that were identified in the respective lineup position. The frequencies of lineup rejections refer to the number of rejections of culprit-present and culprit-absent lineups in which the culprits or innocent suspects were placed in the respective lineup position. The guessing-based-selection parameter g of the 2-HT eyewitness identification model thus refers to the probability of selecting a lineup member based on guessing in each lineup position. Because the lineup positions of all six lineup members were completely randomized, guessing-based selection results in the selection of the suspect with the probability given by the reciprocal of the lineup size. Therefore, the constant $1 \div$ *lineup size* was set to 0.16667, an approximation of the reciprocal of the lineup size.

The first step in applying a multinomial processing tree model is to find a base model that accurately describes the data. Model fit is evaluated by performing a goodness-of-fit test to assess the discrepancy between the observed data and the data predicted by the model. The goodness-of-fit statistic G^2 is approximately chi-square distributed with degrees of freedom indicated in parentheses. If a goodness-of-fit test is non-significant, this attests that the model fits the data. In the base model, parameter dA was set to be equal across all lineup positions as the detection of the absence of the culprit was not expected to vary with lineup position. This base model fit the data, $G^2(5)=6.83$, $p=.234$. Parameter dA was estimated to be 0.02 ($SE=0.03$). Parameter estimates for the culprit-presence-detection parameter dP and the guessing-based-selection parameter g are displayed in Fig. 2.

Multinomial processing tree models allow for testing hypotheses directly at the level of the parameters representing the cognitive processes underlying the observable behavior[32,46]. For example, the hypothesis that culprit-presence detection differs as a function of lineup position can be tested by restricting parameter dP to be equal across the six lineup positions. This equality restriction generates five degrees of freedom. If this equality restriction significantly decreases the model's fit to the data relative to the fit of the base model, it can be concluded that culprit-presence detection differs as a function of lineup position. Restricting the culprit-presence-detection-parameter dP to be equal across all lineup positions did not significantly decrease the model fit, $\Delta G^2(5)=5.09$, $p=.405$. This leads to the conclusion that the process of culprit-presence detection does not differ as a function of lineup position.

In contrast, restricting the guessing-based-selection parameter g to be equal across all lineup positions significantly decreased the model fit, $\Delta G^2(5)=35.98$, $p<.001$. When each position was compared to each of the other lineup positions using Bonferroni-Holm-adjusted alpha levels to control for alpha error accumulation[58], guessing-based selection differed significantly between Position 1 and each of the other lineup positions. Beyond that, there were no significant differences in guessing-based selection for all other pairwise comparisons of lineup positions (see Table 2). This leads to the conclusion that lineup members placed in Position 1 run a higher risk of being selected based on guessing than lineup members placed in other positions.

	Lineup position					
	1	2	3	4	5	6
Culprit-present lineups						
Culprit identifications	313 (0.18)	290 (0.17)	275 (0.16)	242 (0.14)	285 (0.17)	289 (0.17)
Filler identifications	269 (0.21)	229 (0.18)	213 (0.16)	200 (0.15)	179 (0.14)	207 (0.16)
False lineup rejections	371 (0.17)	353 (0.16)	372 (0.17)	356 (0.16)	345 (0.16)	384 (0.18)
Culprit-absent lineups						
Innocent-suspect identifications	113 (0.19)	97 (0.17)	93 (0.16)	88 (0.15)	87 (0.15)	107 (0.18)
Filler identifications	359 (0.22)	251 (0.15)	263 (0.16)	265 (0.16)	244 (0.15)	273 (0.16)
Correct lineup rejections	462 (0.16)	511 (0.17)	468 (0.16)	476 (0.16)	535 (0.18)	480 (0.16)

Table 1. Observed response frequencies and proportions (in parentheses) as a function of lineup position in Experiment 1 (simultaneous lineups). The frequencies and proportions of culprit and innocent-suspect identifications refer to the number of culprits and innocent suspects that were identified in each lineup position in culprit-present and culprit-absent lineups, respectively. Similarly, the frequencies and proportions of filler identifications in culprit-present and culprit-absent lineups refer to the number of fillers that were identified in the respective lineup position. The frequencies and proportions of false and correct lineup rejections refer to the rejections of the culprit-present and culprit-absent lineups in which culprits or innocent suspects were placed in the respective lineup position. The proportions are rounded to two decimal places and therefore do not always add up exactly to 1.

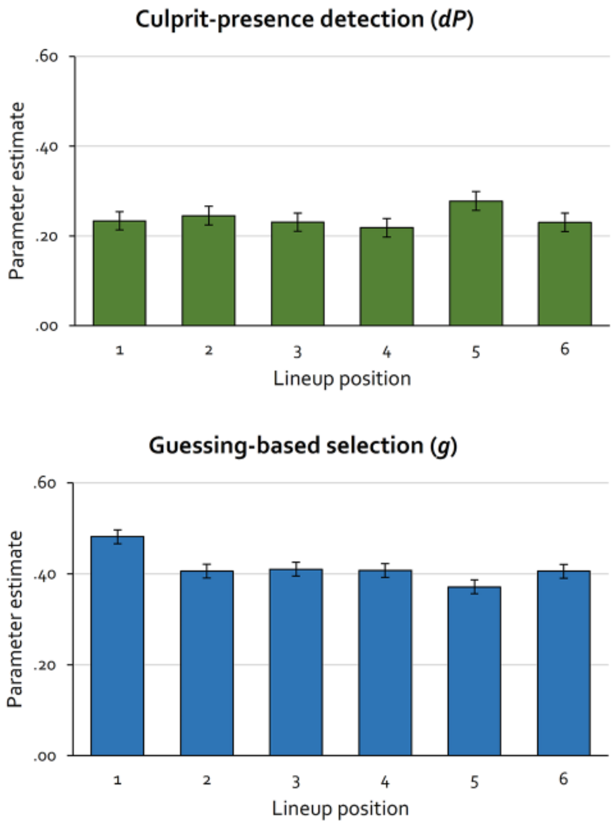

Figure 2. Estimates of parameters *dP* (culprit-presence detection; upper panel) and *g* (guessing-based selection; lower panel) as a function of lineup position in Experiment 1 (simultaneous lineups). The error bars represent standard errors.

Lineup-position comparison	$\Delta G^2(1)$	*p*	Bonferroni-Holm-adjusted alpha level
1 vs. 5	**32.21**	**<0.001**	**0.003 (0.05 ÷15)**
1 vs. 6	**15.49**	**<0.001**	**0.004 (0.05 ÷14)**
1 vs. 2	**15.35**	**<0.001**	**0.004 (0.05 ÷13)**
1 vs. 4	**14.60**	**<0.001**	**0.004 (0.05 ÷12)**
1 vs. 3	**13.46**	**<0.001**	**0.005 (0.05 ÷11)**
3 vs. 5	3.90	0.048	0.005 (0.05 ÷ 10)
4 vs. 5	3.26	0.071	0.006 (0.05 ÷ 9)
2 vs. 5	3.10	0.078	0.006 (0.05 ÷ 8)
5 vs. 6	3.04	0.081	0.007 (0.05 ÷ 7)
3 vs. 6	0.06	0.809	0.008 (0.05 ÷ 6)
2 vs. 3	0.05	0.821	0.01 (0.05 ÷ 5)
3 vs. 4	0.03	0.870	0.013 (0.05 ÷ 4)
4 vs. 6	0.01	0.939	0.017 (0.05 ÷ 3)
2 vs. 4	0.00	0.951	0.025 (0.05 ÷ 2)
2 vs. 6	0.00	0.988	0.05 (0.05 ÷ 1)

Table 2. Test statistics, *p*-values and the respective Bonferroni-Holm-adjusted alpha levels for the tests comparing guessing-based selection at each lineup position to guessing-based selection at each of the other lineup positions in Experiment 1. Comparisons are sorted by *p*-value and comparisons with statistically significant differences are typeset in bold. *b* Table 3. B $\Delta G^2(5) = 1.95$, *p*

Parameter estimates for the biased-suspect-selection parameter b are shown in Table 3. Biased suspect selection did not differ significantly across lineup positions, $\Delta G^2(5) = 1.95$, $p = .856$. Descriptively, the estimates are low which reflects the fact that the lineups were constructed to be fair.

Discussion
The model-based analyses of the data of Experiment 1 lead to the conclusion that lineup position has no effect on the detection-based processes underlying eyewitness responses in simultaneous lineups. Participants were just as likely to detect the presence of the culprit when he was placed in edge positions as when he was placed in middle positions. This finding is consistent with most previous research showing that lineup position has no effect on the rate of culprit identifications or the ability to discriminate between culprits and innocent suspects in simultaneous lineups[6,28,48]. These results are also in line with Palmer et al.'s[21] proposition that participants are motivated to make accurate decisions and therefore attend the photos in all lineup positions equally closely. In the model-based analysis of guessing-based selection, there was no evidence that participants were more likely to select lineup members placed in middle positions based on guessing. Instead, guessing-based selection was increased for the lineup member placed in Position 1, the leftmost position of the lineup, with no pairwise differences between the other lineup positions. As a side note, this finding is already evident in the raw response frequencies (Table 1) as participants made more selections of suspects and fillers combined in Position 1 (1054 selections) than in any other position ($\leq$876 selections in every other position). This result is consistent with findings showing that people have an increased tendency to select lineup members that are placed earlier in the reading direction compared to lineup members placed later[21,49,50].

Experiment 2
In Experiment 2, we investigated the effects of lineup position on the detection-based and non-detection-based processes in sequential lineups in which the lineup members are presented one after another. Sequential lineups were first proposed by Lindsay and Wells in 1985 as an alternative to simultaneous lineups[59] and have since been included in guidelines for lineups in various jurisdictions[13,60,61].

As in Experiment 1, the first aim of Experiment 2 was to test whether lineup position affects the detection of the presence of the culprit. A priori, it was unclear whether, and, if so, how, lineup position might affect the detection of the presence of the culprit in sequential lineups. On the one hand, as more and more faces are shown, participants may gain more insight into the detection task, which could help their performance[62]. On the other hand, interference may build up due to the increasing number of faces seen previously in the lineup that might act as visually similar distractors[63]. Empirically, many studies have found no effect of lineup position on the rate of culprit identifications or the ability to discriminate between culprits and innocent suspects in sequential lineups[7,20,23,47,59,64]. In contrast, there are also some studies showing effects of lineup position in sequential lineups, but these reports are inconsistent. Some studies suggest that there is an advantage of placing the suspect in earlier positions[6,48,65] while others suggest that there is an advantage of placing the suspect in later positions[24,28,49,66].

The second aim of Experiment 2 was to test whether lineup position affects guessing-based selection. In several previous studies, lineup position had no effect on overall identification rates, rejection rates or the response criterion in sequential lineups[23,59,64]. However, there are also studies suggesting that people are more likely to select lineup members in earlier positions[27,49,50] or later positions[28,65]. It was thus an open question as to whether the effects of Experiment 1—increased guessing-based selection in Position 1 with no differences between the other lineup positions— would be replicated in Experiment 2.

Method
Participants
Participants were recruited and compensated through the research panel of Bilendi GmbH (https://www.bilendi.de). Of the data files of the participants who filled out the socio-demographic questionnaire at the beginning of Experiment 2, a total of 476 were excluded because the participants either did not complete the experiment or revoked the consent to the use of their data, 132 were excluded because the participants saw the staged-crime video more than once and 44 were excluded because the participants failed the attention check. The final sample included 2581 participants (1141 female, 1438 male, 2 diverse) with a mean age of 54 years ($SD = 16$). The sample was characterized by a diversified level of education: Secondary education had been completed by around 46 % of the participants, around 21 % of the participants also had obtained university entrance qualification and around 33 % also had obtained a university degree or a comparable qualification. A sensitivity analysis conducted using G*Power[51] indicated that, with 6179 data points (fewer than to be expected based on the number of participants because only lineups with at most one identification were included in the data analysis, see Procedure section) and $\alpha = \beta = 0.05$, it was possible to detect effects of lineup position on the model parameters as small as $w = 0.06$ in goodness-of-fit tests with $df = 5$ (comparison of all lineup positions simultaneously, see Results section).

	Lineup position					
	1	2	3	4	5	6
Biased suspect selection	0.05 (0.01)	0.05 (0.01)	0.05 (0.01)	0.04 (0.01)	0.04 (0.01)	0.06 (0.01)

Table 3. Estimates and standard errors (in parentheses) of parameter b (biased suspect selection) as a function of lineup position in simultaneous lineups in Experiment 1.

Materials

Materials were the same as those used in Experiment 1.

Procedure

The procedure was the same as the one used in Experiment 1 except that lineups were presented sequentially instead of simultaneously. In the sequential lineups, photos of the lineup members were presented one at a time in a randomized order. Participants had to decide for each lineup member whether he was a culprit or not. They could click the button "Yes, was present" underneath the photo or the button "No, this person was not present" to indicate their decision. Once participants had made their decision, they could proceed to the next lineup member by clicking the "Next" button. Irrespective of their responses, participants were shown all six lineup members. After the sixth lineup member, the lineup ended. If participants did not select any of the lineup members, the lineup was classified as rejected.

In sequential lineups, it is possible that eyewitnesses identify more than one lineup member, in which case the lineup administrators must decide on how to interpret the eyewitnesses' identifications. In the past, researchers often used instructions emphasizing that only the first identification in the lineup would count[4,25,49,67] to evade this issue. In some studies, participants did not even see the remaining lineup members after having made an identification because the lineup was terminated immediately[6,7,47,64]. This is contrary to how lineups are conducted in the real world[68]. Lineup administrators likely want to avoid terminating the lineup procedure before the suspect's face has been shown. Furthermore, defense lawyers could argue that the lineup consisted of fewer than the required number of lineup members if a lineup was terminated early. Therefore, jurisdictions[60,61] often require lineup administrators to always show all lineup members. In this case, one could argue that research should follow standard police procedure in order to arrive at valid conclusions[43,68]. With respect to position effects, Horry et al.[68] have pointed out that the first-yes-counts rule alone could induce a position effect in the response rates by inflating the rate of initial identifications being accepted as valid. Counting the last identification under the reasoning that it revises earlier ones might cause position effects in the opposite direction. Since the aim of this experiment was to investigate position effects in sequential lineups as employed in police practice, we did not give first-yes-counts instructions. Additionally, because we aimed to investigate position effects on the cognitive processes underlying eyewitness responses instead of the consequences of decisions on how to analyze the data, we followed the approach of previous studies[69–71] of only including lineups with no more than one identification (around 60 %) in our analyses.

Results

The observed response frequencies that formed the basis of our analyses are reported in Table 4. We used the same base model as in Experiment 1. This base model fit the data, $G^2(5)=6.79$, $p=.237$. Parameter dA was estimated to be 0.00 ($SE=0.03$). Parameter estimates for the culprit-presence-detection parameter dP and the guessing-based-selection parameter g are displayed in Figure 3.

Parallel to the results of Experiment 1, restricting the culprit-presence-detection parameter dP to be equal across all lineup positions did not significantly decrease the model fit, $\Delta G^2(5)=7.88$, $p=.163$. This leads to the conclusion that the process of culprit-presence detection does not differ as a function of lineup position. Also

	Lineup position					
	1	**2**	**3**	**4**	**5**	**6**
Culprit-present lineups						
Culprit identifications	227 (0.23)	194 (0.20)	151 (0.15)	161 (0.16)	136 (0.14)	119 (0.12)
Filler identifications	185 (0.25)	138 (0.19)	122 (0.17)	104 (0.14)	95 (0.13)	89 (0.12)
False lineup rejections	190 (0.15)	215 (0.18)	194 (0.16)	199 (0.16)	194 (0.16)	234 (0.19)
Culprit-absent lineups						
Innocent-suspect identifications	82 (0.24)	65 (0.19)	38 (0.11)	67 (0.20)	40 (0.12)	49 (0.14)
Filler identifications	225 (0.21)	198 (0.18)	174 (0.16)	173 (0.16)	161 (0.15)	151 (0.14)
Correct lineup rejections	280 (0.15)	330 (0.18)	290 (0.16)	331 (0.18)	286 (0.16)	292 (0.16)

Table 4. Observed response frequencies and proportions (in parentheses) as a function of lineup position in Experiment 2 (sequential lineups). The frequencies and proportions of culprit and innocent-suspect identifications refer to the number of culprits and innocent suspects that were identified in each lineup position in culprit-present and culprit-absent lineups, respectively. Similarly, the frequencies and proportions of filler identifications in culprit-present and culprit-absent lineups refer to the number of fillers that were identified in the respective lineup position. The frequencies and proportions of false and correct lineup rejections refer to the rejections of the culprit-present and culprit-absent lineups in which culprits or innocent suspects were placed in the respective lineup position. The proportions are rounded to two decimal places and therefore do not always add up exactly to 1.

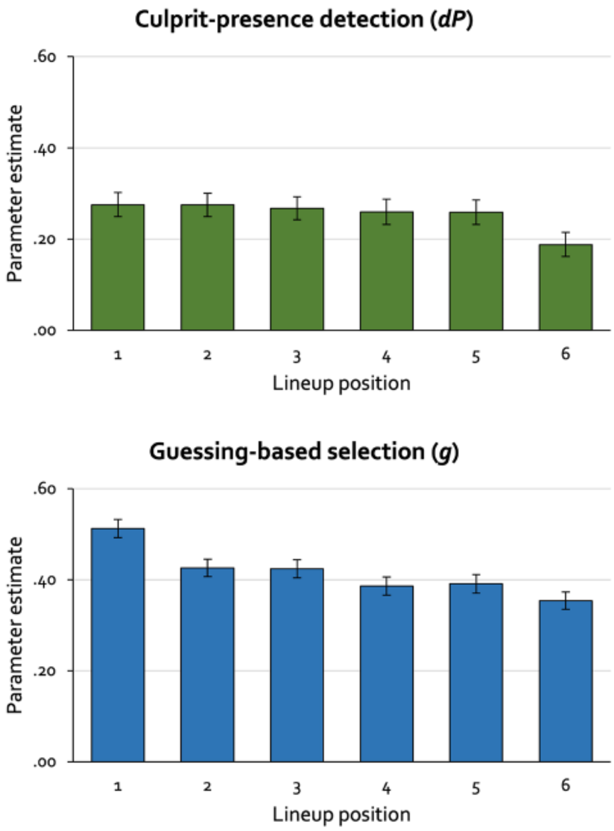

Figure 3. Estimates of parameters *dP* (culprit-presence detection; upper panel) and *g* (guessing-based selection; lower panel) as a function of lineup position in Experiment 2 (sequential lineups). The error bars represent standard errors.

parallel to the results of Experiment 1, restricting the guessing-based-selection parameter *g* to be equal across all lineup positions significantly decreased the model fit, $\Delta G^2(5) = 49.07$, $p < .001$. As in Experiment 1, each position was compared to each of the other positions using Bonferroni-Holm-adjusted alpha levels to control for alpha error accumulation[58]. Guessing-based selection differed significantly between Position 1 and each of the other positions. Beyond that, there were no significant differences in guessing-based selection for all other pairwise comparisons of lineup positions, except that guessing-based selection differed significantly between Position 2 and Position 6 (see Table 5). This leads to the conclusion that lineup members placed in Position 1 run a higher risk of being selected based on guessing than lineup members placed in other positions.

Parameter estimates for the biased-suspect-selection parameter b are shown in Table 6. Biased suspect selection did not differ significantly across lineup positions, $\Delta G^2(5) = 10.90$, $p = .053$. Descriptively, the estimates are low which reflects the fact that the lineups were constructed to be fair.

Discussion

Parallel to the results of Experiment 1, participants showed the same ability to detect the presence of the culprit, no matter the position he was placed in. This conclusion is in line with several previous studies showing that lineup position had no effect on the rate of culprit identifications or the ability to discriminate between culprits and innocent suspects in sequential lineups[7,20,23,47,59,64]. These findings suggest that participants attended to the photos of all lineup members equally closely regardless of their position in the lineup.

In the model-based analysis of guessing-based selection, significant effects of lineup position were found. Specifically, guessing-based selection was increased for the lineup member placed in Position 1, with no consistent differences observed between the other lineup positions. As a side note, this finding is already evident in the raw response frequencies (Table 4) as participants made more selections of suspects and fillers combined in Position 1 (719 selections) than in any other position (≤ 595 selections in every other position). Such a pattern, in turn, is in line with those previous studies that have found that people are more likely to select lineup members in earlier positions[27,49,50]. The observed effect of lineup position on guessing-based selection in sequential lineups is thus parallel to the effect of lineup position on guessing-based selection in simultaneous lineups observed in Experiment 1.

General discussion

When compiling lineups, practitioners as well as researchers often avoid, or recommend to avoid, placing the suspect in Position 1 of a lineup[2,15–20]. However, so far it has been unclear whether this hesitance to place the

Lineup-position comparison	$\Delta G^2(1)$	p	Bonferroni-Holm-adjusted alpha level
1 vs. 4	**26.34**	**< 0.001**	**0.003 (0.05 ÷15)**
1 vs. 5	**23.20**	**< 0.001**	**0.004 (0.05 ÷ 14)**
1 vs. 6	**40.24**	**< 0.001**	**0.004 (0.05 ÷13)**
1 vs. 2	**12.90**	**< 0.001**	**0.004 (0.05 ÷12)**
1 vs. 3	**12.73**	**< 0.001**	**0.005 (0.05 ÷11)**
2 vs. 6	**8.39**	**0.004**	**0.005 (0.05 ÷10)**
3 vs. 6	7.49	0.006	0.006 (0.05 ÷ 9)
2 vs. 4	2.65	0.104	0.006 (0.05 ÷ 8)
3 vs. 4	2.25	0.134	0.007 (0.05 ÷ 7)
5 vs. 6	2.03	0.155	0.008 (0.05 ÷ 6)
2 vs. 5	1.95	0.162	0.01 (0.05 ÷ 5)
3 vs. 5	1.64	0.200	0.013 (0.05 ÷ 4)
4 vs. 6	1.61	0.205	0.017 (0.05 ÷ 3)
4 vs. 5	0.03	0.853	0.025 (0.05 ÷ 2)
2 vs. 3	0.01	0.935	0.05 (0.05 ÷ 1)

Table 5. Test statistics, p-values and the respective Bonferroni-Holm-adjusted alpha levels for the tests comparing guessing-based selection at each lineup position to guessing-based selection at each of the other lineup positions in Experiment 2. Comparisons are sorted by p-value and comparisons with statistically significant differences are typeset in bold.b are shown in table 6.

	Lineup position					
	1	2	3	4	5	6
Biased suspect selection	0.06 (0.02)	0.04 (0.01)	0.01 (0.01)	0.06 (0.02)	0.02 (0.01)	0.04 (0.01)

Table 6. Estimates and standard errors (in parentheses) of parameter b (biased suspect selection) as a function of lineup position in sequential lineups in Experiment 2.

suspect in the first position of a lineup is justified. Here the 2-HT eyewitness identification model[30,31] was used to investigate how lineup position affects the detection-based and non-detection-based processes underlying eyewitness responses. To allow for valid conclusions, the lineup members were randomly assigned to each of the six lineup positions. Furthermore, large sample sizes were used to attain many data points for each of the lineup positions, ensuring a high sensitivity of the statistical tests assessing the effects of lineup position. This made it possible to examine the cognitive processes underlying eyewitness responses in each lineup position separately, without limiting the analyses to certain lineup positions or aggregating over lineup positions. To achieve a comprehensive assessment of the effects of lineup position, Experiment 1 served to investigate effects of lineup position in simultaneous lineups and Experiment 2 was focused on sequential lineups. Our model-based analyses of lineup-position effects revealed a consistent pattern for both types of lineups. First, there were no lineup-position effects on the ability to detect the presence of the culprit, neither in simultaneous nor in sequential lineups. These results are in line with previous research showing no effects of lineup position on the rate of culprit identifications or the ability to discriminate between culprits and innocent suspects in simultaneous lineups[6,28,48] and sequential lineups[7,20,23,47,59,64]. These findings lead to the conclusion that participants attended to all photos equally closely regardless of the lineup position in which the photos were presented.

However, in both simultaneous and sequential lineups, participants were significantly more likely to make a guessing-based selection of the lineup member placed in Position 1—a particularly salient position in both simultaneous and sequential lineups—than of the lineup members placed in other positions. The finding that guessing-based selection is increased in Position 1 combined with the finding that there were no consistent differences between the other lineup positions at first glance validates the reluctance of lineup administrators to place the suspect in the first position[15]. If the suspect is innocent, the risk of a false identification due to guessing-based selection is increased. If the suspect is guilty, placing the suspect in first position may increase the risk that the lineup evidence is discarded in court due to the potentialy inflated influence of guessing-based selection in the identification of the suspect. A straightforward solution seems to be to avoid placing the suspect in Position 1 of lineups[2,15–20] to decrease the probability that the suspect is selected based on guessing. However, if eyewitnesses became aware that the suspect never appears in the first position, they could strategically disregard the lineup member presented in Position 1. This could reduce the functional size of the lineup and effectively turn Position 2 into the new Position 1, in which case the problem would not be solved at all. To remedy the problem, one should first try to achieve an even distribution of guessing-based selections of lineup members across all lineup positions, for example by informing witnesses that lineup members were assigned to positions randomly or by using an array shape without any particularly salient positions[21]. Second, one should try to reduce the probability of guessing-based selections as much as possible, for example by using lineup instructions that discourage guessing-based selection[43,45].

Following studies by Clark and Davey[48] and Meisters et al.[28], we displayed all lineup members in a single row in simultaneous lineups. This lineup format represents one possible format to present simultaneous photo lineups[13] that approximates the layout in in-person lineups. Furthermore, this lineup format simplifies the interpretation of the results by ensuring that lineup position changes in only one dimension in both simultaneous and sequential lineups where photos are presented in a horizontal and a temporal order, respectively. In contrast, presenting the simultaneous lineups in a two-dimensional array would introduce two spatial dimensions, the horizontal and the vertical dimension, complicating the interpretation of the results and differing more from sequential lineups. However, in some jurisdictions, for instance in the USA[19], simultaneous photo lineups are presented as two-dimensional arrays such as two rows of three photos. It is unclear whether and how the effects of position in simultaneous lineups reported here generalize to this two-dimensional format, as it was not possible to examine position effects that may occur only in two-dimensional arrays, such as top-row biases, in the present Experiment 1. Therefore, further research is needed to examine the effects of position on culprit-presence detection and guessing-based selection in two-dimensional arrays (for analyses pertaining to identification rates and discriminability, see[21,29]).

Another limitation of the present research is that the analysis of sequential lineups included data only from those sequential lineups in which at most one identification was made. We thereby ensured that we analyzed the effects of lineup position on the cognitive processes rather than consequences of decisions on how to analyze the data. Anecdotally, we have learned from communications with chief inspectors responsible for conducting lineups at the Düsseldorf Police Department that it also occurs in practice that lineups with more than one identification are discarded as evidence, as the validity of such lineups would presumably be questioned by defense lawyers because at least one of the identifications is necessarily false. Nevertheless, this approach limits the generalizability of our findings to sequential lineups where a single identification is made. Specifically, our analyses do not address the effects of lineup position on the cognitive processes underlying eyewitness responses to lineups when more than one identification is made within the same sequential lineup.

Conclusion
The aim of the present study was to gain a better understanding of how lineup position affects the latent cognitive processes underlying eyewitness responses. The widespread concerns about placing the suspect in the first position in lineups documented in the literature[2,15–20] are validated by the present research. The present model-based analyses lead to the conclusion that lineup position had no effect on the detection of the presence of the culprit in simultaneous and sequential lineups. However, guessing-based selection of the lineup members differed as a function of lineup position in both simultaneous and sequential lineups. Specifically, lineup members placed in Position 1 faced a higher risk of being selected based on guessing than lineup members placed in other positions.

Data availability
The data of both experiments are available at the project page of the Open Science Framework under https://osf.io/w582g/.

Received: 4 March 2024; Accepted: 5 November 2024
Published online: 12 November 2024

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Author contributions
CM and NMM developed the experiment and implemented suggestions by RB and AB. CM collected the data and CM and RB analyzed them, taking into account suggestions by NMM and AB. CM wrote the first draft of the manuscript. RB, NMM and AB revised the manuscript. All authors gave final approval for publication.

Funding
The research project reported in this article was supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)—BU 945/10 – 2, project number 456214986.

Open Access funding enabled and organized by Projekt DEAL.

Declarations

Competing interests
The authors declare no competing interests.

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Article 2

This article includes the reanalysis and Experiment 1.

Mayer, C., Bell, R., Menne, N. M., Therre, A., Lichtenhagen, U., & Buchner, A. (2025). Evidence for age-related differences in culprit-presence detection and guessing-based selection in lineups. *Psychology and Aging*, Advance online publication. https://doi.org/10.1037/pag0000916

AMERICAN PSYCHOLOGICAL ASSOCIATION

Psychology and Aging

ISSN: 0882-7974

https://doi.org/10.1037/pag0000916

Evidence for Age-Related Differences in Culprit-Presence Detection and Guessing-Based Selection in Lineups

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The well-validated two-high threshold eyewitness identification model was applied to examine age-related differences in the cognitive processes underlying eyewitness responses to sequential lineups. In the first step, a large data set originally collected for a different purpose was reanalyzed to examine age-related differences in culprit-presence detection, culprit-absence detection, and guessing-based selection among young to middle-aged adults, young–old adults, and old–old adults. In the second step, a novel experiment was conducted to test the robustness of the conclusions from the reanalysis. The results of both analyses are fairly consistent. The probabilities of memory-based culprit-presence detection and, to some degree, culprit-absence detection decrease with age. In contrast, the probability of guessing-based selection increases with age. This shift from memory-based detection to guessing-based selection highlights potential challenges for the validity of eyewitness testimony posed by age-related differences in the cognitive processes underlying eyewitness responses.

Public Significance Statement

The results of the present study show that there are pronounced age-related differences in the cognitive processes that lead to eyewitnesses' responses to lineups. The probability that the participants detect that the culprit is present in a lineup decreases with age. The probability that the participants select a lineup member based on guessing increases with age. There are pronounced differences between young–old and old–old adults, indicating that the decline of memory-based detection and the increase of guessing-based selection become more problematic in the old–old group. These findings draw attention to the cognitive challenges that older eyewitnesses face when participating in lineup tasks.

Keywords: lineups, two-high threshold eyewitness identification model, sequential lineups, age differences

While some cognitive abilities, such as emotional regulation and vocabulary, remain stable or even improve in older adulthood (Carstensen et al., 2000; Park et al., 2002; Salthouse, 2004; Verhaeghen, 2003), others decline during this period (e.g., Aslan & Bäuml, 2013; Borella et al., 2007; Davis et al., 2003; Salthouse, 2004; Schnitzspahn & Kliegel, 2009). Specifically, memory abilities are well documented to decline in old age (Borella et al., 2007; Schnitzspahn & Kliegel, 2009). Age-related changes in memory are particularly important in situations where memory plays a pivotal role, such as eyewitness testimony in police lineups. In lineups, a

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The data and equation files of all analyses have been made publicly available in the Open Science Framework and can be accessed at https://osf.io/5h7zj/. None of the experiments were preregistered. The article is original, not previously published, and not under concurrent consideration elsewhere.

The authors have no conflicts of interest to disclose. This research was funded by the Deutsche Forschungsgemeinschaft (German Research Foundation)—BU 945/10-2, Project Number 456214986.

Carolin Mayer played a lead role in data curation, formal analysis, investigation, methodology, project administration, software, visualization, writing–original draft, and writing–review and editing and an equal role in validation. Raoul Bell played a supporting role in conceptualization, data curation, formal analysis, investigation, methodology, visualization, and writing–review and editing and an equal role in funding acquisition, supervision, and validation. Nicola Marie Menne played a supporting role in conceptualization, data curation, formal analysis, investigation, methodology, software, visualization, and writing–review and editing and an equal role in validation. Amelie Therre played a supporting role in conceptualization, data curation, formal analysis, investigation, methodology, software, visualization, and writing–review and editing and an equal role in validation. Ulla Lichtenhagen played a supporting role in conceptualization, data curation, formal analysis, investigation, methodology, software, visualization, and writing–review and editing and an equal role in validation. Axel Buchner played a supporting role in conceptualization, data curation, formal analysis, investigation, methodology, visualization, and writing–review and editing and an equal role in funding acquisition, supervision, and validation.

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suspect—who may be guilty or innocent—is presented alongside several known-to-be-innocent fillers. The task of the eyewitness is to make an identification if they recognize the suspect or to reject the lineup if they do not. It has been indicated that older eyewitnesses face challenges in this task: older adults are less likely to correctly identify a culprit and more likely to falsely select an innocent suspect or a filler than younger adults (for meta-analyses, see Erickson et al., 2016; Fitzgerald & Price, 2015).

However, these age-related differences in the observed response rates may result from different combinations of age-related differences in the ability to detect the presence of the culprit, the ability to detect the absence of the culprit and the selection of lineup members based on guessing. Without a formal measurement model, the specific combination of cognitive processes responsible for the differences in observed response rates remains unknown. Here, we report a reanalysis of data originally collected for another purpose, alongside a novel experiment, both of which serve to directly measure the processes of culprit-presence detection, culprit-absence detection, and guessing-based selection that underlie lineup responses using the well-validated two-high threshold (2-HT) eyewitness identification model (Menne et al., 2022; Winter et al., 2022).

The 2-HT eyewitness identification model belongs to the general class of multinomial processing tree models which are commonly used in memory research to measure latent cognitive processes underlying observed behavior (Batchelder & Riefer, 1999; Erdfelder et al., 2009; Riefer & Batchelder, 1988). Easy-to-use tutorials (Schmidt et al., 2023) and user-friendly analysis software (Moshagen, 2010) make this class of models highly accessible. The 2-HT eyewitness identification model has already been used in several studies and its usefulness for lineup research has been demonstrated (Bell et al., 2024; Menne et al., 2023a, 2023b; Menne et al., 2025; Therre et al., 2024; Winter et al., 2023). The 2-HT eyewitness identification model implies that observed responses to lineups result from four different latent cognitive processes. Two of those processes are memory-based—culprit-presence detection and culprit-absence detection—and two are not memory-based—biased suspect selection and guessing-based selection. With the model, it is possible to determine the probabilities with which these processes occur. To achieve this, data from all possible response categories in lineups are incorporated: culprit identifications, innocent-suspect identifications, false and correct lineup rejections, and filler identifications in both culprit-present and culprit-absent lineups.

A graphical illustration of the model is depicted in Figure 1. In the 2-HT eyewitness identification model, culprit-presence detection, culprit-absence detection, biased suspect selection, and guessing-based selection are precisely and transparently defined by the model's structure. The labels serve as accessible descriptors to simplify communication. The term "cognitive processes" is used as a neutral umbrella term encompassing all specific processes defined by the model. The model consists of two trees: the upper tree depicts the processes assumed to determine an eyewitness's response in culprit-present lineups. The lower tree depicts the processes assumed to determine an eyewitness's response in culprit-absent lineups.

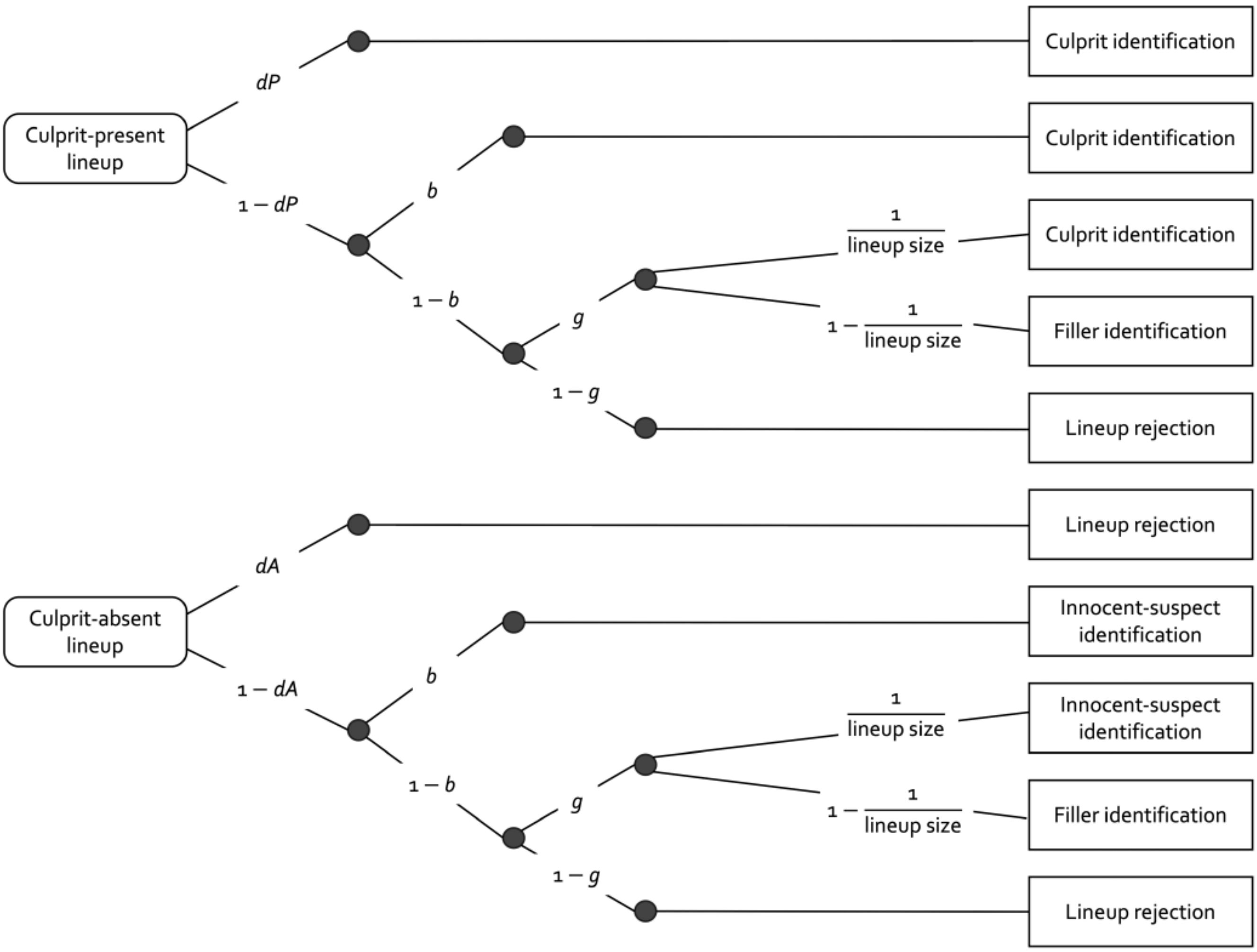
If the culprit is present in the lineup, their presence is detected with probability dP, resulting in a correct culprit identification. If the presence of the culprit is not detected, which occurs with the complementary probability $1 - dP$, then two nonmemory-based processes may determine the eyewitness's response. If the lineup is unfair, that is, if the culprit somehow stands out from the fillers and this is noticed by the eyewitness, then biased suspect selection may occur with the conditional probability b. In case of no biased suspect selection, which occurs with the complementary probability $1 - b$, the eyewitness may select a lineup member based on guessing. In case of a guessing-based selection, which occurs with the conditional probability g, a lineup member is selected by randomly sampling among the lineup members. The random-sampling probability is determined by the lineup size: The culprit is selected with the conditional probability $1 \div$ lineup size, and a filler identification occurs with the complementary probability $1 - (1 \div$ lineup size). For instance, in a six-person lineup, the culprit is selected with a conditional probability of ⅙ and a filler identification occurs with the complementary probability of ⅚. In case of no guessing-based selection, which occurs with the complementary probability $1 - g$, the lineup is falsely rejected.

In culprit-absent lineups, the absence of the culprit is detected with probability dA, resulting in the correct rejection of the lineup. If the absence of the culprit is not detected, which occurs with the complementary probability $1 - dA$, the same nonmemory-based processes as in culprit-present lineups determine the eyewitness's response except that the processes refer to the innocent suspect in lieu of the culprit. The nonmemory-based processes are the same in both culprit-present and culprit-absent lineups because, when neither the presence nor the absence of the culprit is detected, culprit-present and culprit-absent lineups are indistinguishable to the eyewitness.

The 2-HT eyewitness identification model has been validated extensively. Specifically, its parameters have been shown to sensitively capture the cognitive processes they were designed to measure in a series of experiments specifically conducted for validation purposes (Winter et al., 2022) using the same stimulus material as in the studies reported here. These findings also demonstrate, among other things, that the 2-HT eyewitness identification model successfully separates the detection-based processes from each other and from guessing-based selection in eyewitness identifications. What is more, analyses of published data from experiments conducted by different research groups—using various mock-crime scenarios, face stimuli, and lineup procedures—also support the model's validity, demonstrating its robustness across different experimental designs and contexts (Menne et al., 2022). Given this extensive validation, the 2-HT eyewitness identification model may be seen as a valuable tool for disentangling the processes underlying age-related differences in eyewitness performance.

As mentioned above, it has often been observed that older adults exhibit lower rates of correct culprit identifications than younger adults (Colloff et al., 2017; Havard & Memon, 2009; Humphries et al., 2024; Memon & Gabbert, 2003b; Rose et al., 2005; Wilcock et al., 2007; D. B. Wright & Stroud, 2002; Wylie et al., 2015). A possible interpretation of these findings is that older adults may be less likely than younger adults to detect the presence of the culprit. However, the literature on this issue is inconclusive as the age-related decline of correct culprit identifications has not always been reliably observed across studies (Key et al., 2015; Memon & Gabbert, 2003a; Memon et al., 2003; Nyman et al., 2025; Wilcock & Bull, 2010). Furthermore, older adults have been reported to be less likely to correctly reject a culprit-absent lineup compared with younger adults (Erickson et al., 2016; Havard & Memon, 2009; Memon & Gabbert, 2003a; Pica & Pozzulo, 2018; Rose et al., 2005)

Figure 1
The 2-HT Eyewitness Identification Model



Note. The 2-HT eyewitness identification model is illustrated in the form of processing trees. The rounded rectangles on the left represent the two types of lineups that were presented: culprit-present lineups and culprit-absent lineups. The rectangles on the right show the observable response categories. The letters attached to the branches connecting the rounded rectangles and the rectangles represent the probabilities of the latent cognitive processes (dP = culprit-presence detection; dA = culprit-absence detection; b = biased suspect selection; g = guessing-based selection) underlying the observable eyewitness responses to the lineups. Guessing-based selection results in the selection of the (guilty or innocent) suspect with the sampling probability that is given by the reciprocal of the lineup size. 2-HT = two-high threshold.

and to be more likely to select an innocent suspect (Pica & Pozzulo, 2018; Wilcock & Bull, 2010) or a filler (Memon & Gabbert, 2003b; Searcy et al., 1999; Wilcock et al., 2007). At first glance, it may seem straightforward to interpret this pattern of response rates as indicating that older adults are not only less likely than younger adults to detect the presence of the culprit in a lineup but may also be less likely than younger adults to detect the absence of the culprit in a lineup, leading to fewer correct lineup rejections and more false innocent-suspect and filler identifications. However, this interpretation is premature as the same pattern of response rates could alternatively or additionally be attributed to an age-related increase in guessing-based selection. Older adults may make fewer correct lineup rejections and more false innocent-suspect and filler identifications because they are more inclined to make a selection based on guessing, possibly due to a misguided desire to "help" the investigation by providing an identification despite their poor memory capabilities. The fact that the same pattern of response rates may stem from different underlying cognitive processes shows that the interpretation of observed responses remains ambiguous without a formal measurement model. Fortunately, we can move beyond informal speculations about the latent processes by using the 2-HT eyewitness identification model to directly measure culprit-presence detection, culprit-absence detection and guessing-based selection.

In the vast majority of studies on age-related differences in lineup performance, a group of younger adults has been compared with a single group of older adults (Havard & Memon, 2009;

Humphries et al., 2024; Memon & Gabbert, 2003a, 2003b; Memon et al., 2003; Nyman et al., 2025; Pica & Pozzulo, 2018; Rose et al., 2005; Searcy et al., 1999; Wilcock & Bull, 2010; Wilcock et al., 2007; D. B. Wright & Stroud, 2002; Wylie et al., 2015; for an exception, see Scogin et al., 1994). However, researchers in the area of adult cognitive development have found it useful to distinguish between young–old adults and old–old adults because there are appreciable differences between these groups in cognitive functions such as memory (e.g., Aslan & Bäuml, 2013; Borella et al., 2007; Davis et al., 2003; Henry et al., 2015; Schmitter-Edgecombe & Simpson, 2001; Schnitzspahn & Kliegel, 2009). It seems therefore necessary to investigate whether analogous differences also emerge when memory for culprits is probed with lineups. Therefore, we compared younger adults (young to middle-aged in the reanalysis, young in the novel experiment), young–old adults and old–old adults in the two studies that we report on here. First, we report a reanalysis of a large data set originally collected for a different purpose. Second, we report the results of a novel experiment specifically conducted to test the reliability and robustness of the findings obtained in the reanalysis. In both the reanalysis and the novel experiment, we focused on sequential lineups as a sequential lineup format is recommended or even required in many jurisdictions (Federal/Provincial/Territorial Heads of Prosecutions—Subcommittee on the Prevention of Wrongful Convictions, 2018; German Federal Ministry of the Interior and Community, 2023; Home Office, 2017; Norwegian Riksadvokaten, 2013; Tupper, 2017).

Reanalysis

First, we reanalyzed data collected by Mayer et al. (2024, Experiment 2). These data were originally collected for a different purpose so that age-related differences have not yet been analyzed. We used this data set because it contains data from a large number of participants and covers a wide age range (see below). We compared young to middle-aged adults, young–old adults, and old–old adults. We categorized participants aged 60 to 74 years as young–old adults and participants aged 75 years or older as old–old adults based on analogous categorizations in studies on memory-related research questions (e.g., Aslan & Bäuml, 2013; Borella et al., 2007; Lamont et al., 2005; Schnitzspahn & Kliegel, 2009; A. M. Wright & Holliday, 2007). For simplicity, participants aged 59 years or younger were categorized into one group of young to middle-aged adults.

Method

Transparency and Openness

The data and model equations necessary for our model-based analyses are available at https://osf.io/5h7zj/ (Mayer et al., 2025). The staged-crime videos cannot be provided because we do not have permission from the actors to distribute the videos beyond the context of conducting experiments. We report on data exclusions and all measures. Data analysis was conducted using multitree (Moshagen, 2010). The reanalysis was not preregistered.

Participants

In the study of Mayer et al. (2024), the participants, who were residents of Germany, were recruited through the research panel of Bilendi GmbH (https://www.bilendi.de). Of the data files of participants who had filled out the sociodemographic questionnaire at the beginning of the experiment, 476 were excluded because the participants either did not complete the experiment or revoked the consent to the use of their data, 132 were excluded because the participants saw the staged-crime video more than once, and 44 were excluded because the participants failed the attention check (see the Procedure section). The final sample consisted of 2,581 participants (1,141 female, 1,438 male, two diverse). Out of these, 1,452 participants were classified as young to middle-aged adults (aged 18–59 years, $M = 42$, $SD = 12$), 992 participants were classified as young–old adults (aged 60–74 years, $M = 67$, $SD = 4$), and 137 participants were classified as old–old adults (aged 75 years or older, $M = 79$, $SD = 4$). As was to be expected due to changes in the education system over the past decades, there were differences in the levels of education among these groups. Specifically, a larger proportion of the young to middle-aged adults had obtained at least a university entrance qualification (62%) compared with the young–old adults (44%) and the old–old adults (39%).

Materials

In the study of Mayer et al. (2024, Experiment 2), the same staged-crime videos, suspect photographs, filler photographs, and lineup design were used as in previous studies which used the 2-HT eyewitness identification model (Bell et al., 2024; Menne et al., 2023a, 2023b; Menne et al., 2025; Therre et al., 2024; Winter et al., 2022, 2023).

Staged-Crime Videos. Participants watched one of two staged-crime videos. In both videos, four white, young and male culprits wearing fan clothing of the German soccer club FC Bayern München assaulted a white, young and male victim wearing fan clothing of the German soccer club Borussia Dortmund. By including four culprits in the videos, we obtained four data points per participant and thereby increased the statistical sensitivity of the model-based analyses. This staged-crime scenario is ecologically valid given that a notable share of real-world crimes is committed by multiple culprits (Hobson et al., 2013; Hobson & Wilcock, 2011; Tupper et al., 2019). The videos showed the culprits approaching the victim at a bus stop and verbally harassing him. They then started taking some of the victim's belongings and tossed them around. Next the culprits began to attack the victim physically, eventually knocking him to the ground. When the culprits became aware that another person was approaching (not visible in the video), they desisted and fled.

Both videos showed the same plot and actions in the same sequence and timing, lasted for about 130 s and were displayed at a resolution of 885×500 pixels. The videos only differed in the actors portraying the culprits and the victim. However, the actors were selected so that the actor portraying a specific culprit in Video A resembled the actor portraying the corresponding culprit in Video B in body shape, hair color, and hairstyle. Analogously, the victim in Video A resembled the victim in Video B. Both videos showed all culprits' faces in a clear and frontal view.

Lineups. Participants were presented with four lineups, two culprit-present lineups and two culprit-absent lineups. Each lineup consisted of one suspect and five fillers. Culprit presence was manipulated using the crossed-lineup procedure (Bell et al., 2024; Menne et al., 2023a, 2023b; Menne et al., 2025; Therre et al., 2024; Winter et al., 2022, 2023). In the two culprit-present lineups, the suspect was one of the culprits from the video that the participants had seen. In the two culprit-absent lineups, the suspect was one of the culprits from the video that the participants had not seen. For instance, if participants had seen Video A, then the culprit-present lineups featured two randomly selected culprits, say Culprits 1 and 4, from Video A, while the culprit-absent lineups featured Culprits 2 and 3 from Video B.

The photographs of the fillers were taken from the Center for Vital Longevity Face Database (Minear & Park, 2004). These photographs depicted white men who were between 18 and 29 years old. The fillers were selected to resemble the culprits in body shape, hair color, and hairstyle. The photographs of the fillers and the suspects were matched for lighting and face size. They were presented at a resolution of 142 × 214 pixels. Using the crossed-lineup procedure ensured, first, that there were no systematic differences between culprits and innocent suspects and, second, that the photographs of the culprits and innocent suspects differed to the same degree from the photographs of the fillers. This is parallel to police practice in which the photograph of the suspect, whose guilt or innocence is yet to be determined, is often taken from a different source (e.g., social media) than the filler photographs which are usually obtained from face databases (Bergold & Heaton, 2018).

Procedure

The procedure closely followed the one reported by Bell et al. (2024), Menne et al. (2025); Menne et al. (2023a, 2023b), Therre et al. (2024), and Winter et al. (2022, 2023). The experiment was programmed and administered using SoSci Survey (Leiner, 2023). After having provided their informed consent and having filled out a sociodemographic questionnaire, participants saw one of the staged-crime videos described above. It was determined randomly which of the two videos was shown. Participants could not fast-forward, pause, or replay the video. Following the video, participants were presented with an attention-check question. Out of ten possible responses, participants had to correctly indicate that the persons appearing in the video were “soccer fans.” If participants failed to select the correct response, the experiment was terminated. Otherwise, participants received the lineup instructions.

In the lineup instructions, participants were informed that they would see several lineups. They were asked to identify the culprits from the video. They were informed that a lineup might or might not contain a culprit and that it was equally important to identify the culprit when the culprit was present and to reject the lineup when the culprit was absent. They were not informed about the number of lineups that would follow.

After having completed the attention-check question and after having read the instructions for the lineups, participants were presented with four lineups in a random order. Two of the four lineups were randomly determined to be culprit-present lineups while the other two were culprit-absent lineups. The lineups were presented in a sequential format, so that photographs of the six lineup members were presented one at a time in a random order. Participants selected one of the lineup members as a culprit by clicking the button labeled “Yes, was present” underneath the photograph. Otherwise, they clicked the button labeled “No, this person was not present.” Participants were required to make a response for each lineup member before proceeding to the next lineup member by clicking the “Next” button. Irrespective of their responses, participants were shown all six lineup members. If participants did not select any of the lineup members as the culprit, the lineup was classified as rejected. As in many previous experiments (Bell et al., 2024; Menne et al., 2023a, 2023b; Therre et al., 2024; Winter et al., 2022; but different from Mayer et al., 2024) if participants selected more than one lineup member as the culprit, the final selection was considered to be a revision of any earlier selections and was included in the data analysis.

Results

All goodness-of-fit tests and parameter estimates reported in this article were obtained using multiTree (Moshagen, 2010). For the analysis of the observed response frequencies reported in Table 1, we needed three instances of the 2-HT eyewitness identification model depicted in Figure 1, one for each age group. It is useful to start with a base model for which it can be tested whether it fits the observed data. Given that six-person lineups were used, the constant 1 ÷ lineup size was set to .16667 as an approximation of ⅙. Parameter *b* was set to be equal across all age groups because the same suspect and filler photographs were shown to all participants and, hence, lineup fairness was necessarily the same in all age groups. This base model fit the data, $G^2(2) = 1.78$, $p = .410$. Parameter *b* was estimated to be .04 ($SE = .01$). Parameter estimates for culprit-presence detection (*dP*), culprit-absence detection (*dA*), and guessing-based selection (*g*) are displayed as a function of age group in Panels A, B, and C of Figure 2, respectively.

With multinomial processing tree models, hypotheses can be tested directly at the level of the parameters representing the cognitive processes (Erdfelder et al., 2009; Schmidt et al., 2023). For instance, to test the hypothesis that the probability of culprit-presence detection differs between young to middle-aged adults and young–old adults, parameter *dP* is set to be equal across these two groups. If this equality restriction significantly decreases the model’s fit to the observed data relative to the fit of the base model without this equality restriction, it can be inferred that the probability of culprit-presence detection differs between young to middle-aged adults and young–old adults.

As can be seen in Panel A of Figure 2, parameter *dP* which represents culprit-presence detection decreases with increasing age.

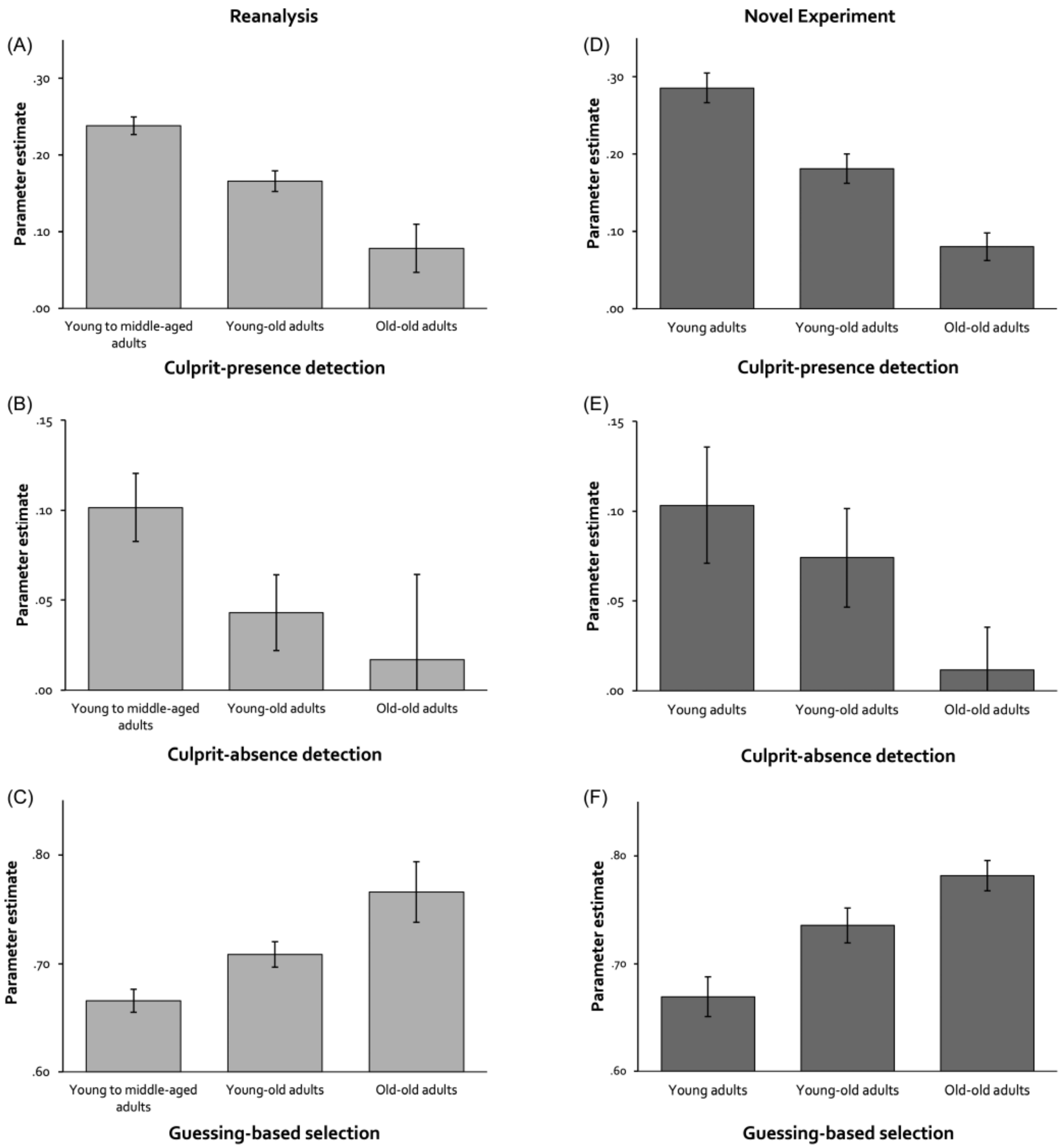
Table 1
Response Frequencies in the Three Age Groups

	Age group		
Lineup type	Young to middle-aged adult	Young–old adult	Old–old adult
Culprit-present lineups			
Culprit identifications	1,020 (.35)	586 (.30)	63 (.23)
Filler identifications	1,176 (.40)	937 (.47)	154 (.56)
False lineup rejections	708 (.24)	461 (.23)	57 (.21)
Culprit-absent lineups			
Innocent-suspect identifications	383 (.13)	306 (.15)	38 (.14)
Filler identifications	1,392 (.48)	1,063 (.54)	171 (.62)
Correct lineup rejections	1,129 (.39)	615 (.31)	65 (.24)

Note. Observed response frequencies (proportions in parentheses) as a function of age group.

Figure 2

Parameter Estimates of the Reanalysis and the Novel Experiment



Note. Estimates of parameters *dP* (culprit-presence detection, Panels A and D), *dA* (culprit-absence detection, Panels B and E), and *g* (guessing-based selection, Panels C and F) as a function of age group in the reanalysis (Panels A, B, and C) and in the novel experiment (Panels D, E, and F). Error bars represent standard errors.

Restricting the culprit-presence-detection parameter *dP* to be equal in young to middle-aged adults and young–old adults significantly reduced the model's fit compared with the fit of the base model, $\Delta G^2(1) = 19.73$, $p < .001$. It can thus be concluded that the probability of the memory-based process of culprit-presence detection differed between young to middle-aged adults and young–old adults. The probability of culprit-presence detection also differed significantly between young–old adults and old–old adults, $\Delta G^2(1) = 6.36$, $p = .012$.

Descriptively the pattern is the same for parameter *dA* which represents culprit-absence detection: As shown in Panel B of Figure 2, the probability of culprit-absence detection decreases with increasing age. The probability of culprit-absence detection differed significantly between young to middle-aged adults and young–old adults, $\Delta G^2(1) = 4.38$, $p = .036$, but the difference between young–old adults and old–old adults was not statistically significant, $\Delta G^2(1) = 0.26$, $p = .609$.

Descriptively, parameter *g* which represents the probability of selecting a person from the lineup based on guessing increases with increasing age, as shown in Panel C of Figure 2. The probability of guessing-based selection differed significantly between young to middle-aged adults and young–old adults, $\Delta G^2(1) = 7.20$, $p = .007$, and between young–old adults and old–old adults, $\Delta G^2(1) = 4.83$, $p = .028$.

Discussion

The model-based reanalysis of age-related differences in the data obtained by Mayer et al. (2024, Experiment 2) reveals pronounced differences between age groups in the latent cognitive processes underlying observable eyewitness responses to lineups. The probability of culprit-presence detection decreases with age, as does the probability of culprit-absence detection, albeit for culprit-absence detection only the difference between young to middle-aged adults and young–old adults reached statistical significance while the descriptive difference between young–old and old–old adults did not. In contrast, the probability of guessing-based selection increases with age. In essence, the contribution of memory-based processes to lineup responses decreases with increasing age whereas the contribution of the nonmemory-based guessing process increases.

A limitation of this reanalysis is that the data were not collected specifically for the purpose of analyzing differences among age groups. Even though the data of Mayer et al. (2024, Experiment 2) cover a wide age range, the number of participants assigned to the three age groups differed considerably, with fewer participants in the old–old group compared with the other groups. As a consequence, the sensitivity of the statistical tests differed as well. This seems most noticeable in the results pertaining to parameter *dA* which was found to differ significantly between the largest group ($n = 1{,}452$ young to middle-aged adults) and the second-largest group ($n = 992$ young–old adults) but not between the second-largest group ($n = 992$ young–old adults) and the smallest group ($n = 137$ old–old adults). It is possible that the finding of a significant difference between the young to middle-aged adults and the young–old adults was mainly due to the particularly high sensitivity of the relevant statistical test. Additionally, the variation in age in the group labeled as young to middle-aged adults ($SD = 12$) was much wider than in the other two groups ($SD = 4$). We therefore conducted a novel experiment specifically designed to compare age groups to test whether the results presented above can be replicated with approximately equal group sizes and more similar age variances in the groups. To achieve this, we included a young adult group instead of the young to middle-aged adult group in the novel experiment. Supplementary analyses of the data from Mayer et al. (2024), Experiment 2 (reported at https://osf.io/5h7zj/?view_only=70fa77dedf8d4ccb93f624476cc30720) showed that there were no significant differences in guessing-based selection and culprit-absence detection between young adults (18–35 years old) and middle-aged adults (36–59 years old), whereas there was a significant difference in culprit-presence detection, with young adults being more likely to detect the culprit's presence than middle-aged adults. By only including the young adults in the new experiments, we thus increased the contrast of our youngest group to the young–old and old–old groups.

Novel Experiment

We conducted a novel experiment using the same design, materials, and procedure as Mayer et al. (2024, Experiment 2). We made sure that the age range in the young–adult group was close to the age range in typical young–adult groups in research on age-related differences (e.g., Borella et al., 2006; Kausler et al., 1988; Schmitter-Edgecombe & Simpson, 2001; A. M. Wright & Holliday, 2007). Specifically, participants assigned to the group of young adults were between 18 and 35 years old, as in several previous studies examining age-related differences in lineup performance (Havard & Memon, 2009; Humphries et al., 2024; Scogin et al., 1994; Wilcock & Bull, 2010). Note, however, that the definition of young adults has been narrower in other studies, with upper age limits of 25 or 30 years (Colloff et al., 2017; D. B. Wright & Stroud, 2002; Yarmey & Kent, 1980). We also made sure to recruit an approximately equal number of young adults, young–old adults, and old–old adults.

Method

Transparency and Openness

The data and model equations necessary for our model-based analyses are available at https://osf.io/5h7zj/?view_only=70fa77dedf8d4ccb93f624476cc30720 (Mayer et al., 2025). The staged-crime videos cannot be provided because we do not have permission from the actors to distribute the videos beyond the context of conducting experiments. We report how our sample size was determined, any data exclusions, and all measures. Data analysis was conducted using multitree (Moshagen, 2010). The experiment was not preregistered.

Participants

Participants, who were residents of Germany, were recruited and compensated for participation through the research panel of Bilendi GmbH (https://www.bilendi.de). Data were collected in 2024. Of the 2,454 data files of the participants who had filled out the sociodemographic questionnaire at the start of the experiment, 727 were excluded because the participants either did not complete the experiment or revoked their consent to the use of their data, 103 were excluded because the participants' ages were outside the age ranges of interest in the present experiment, 88 were excluded because the participants saw the staged-crime video more than once and 23 were excluded because the participants failed the attention check. The final sample consisted of 1,513 participants (550 female, 959 male, four diverse). The young–adult group consisted of 510 participants aged 18–35 years (M = 29, SD = 5), the young–old adult group consisted of 502 participants aged 60–74 years (M = 66, SD = 4), and the old–old adult group consisted of 501 participants aged 75 years or older (M = 78, SD = 3). As was to be expected due to changes in the education system over the past decades, there were differences in the levels of education among the groups. Specifically, a larger proportion of the young adults had obtained at least a university entrance qualification (79%) compared with the young–old adults (47%) and the old–old adults (52%).

Ethics Statement

The experiment is part of a series of experiments that have been approved by the ethics committee of the Faculty of Natural Sciences and Mathematics of Heinrich Heine University (BU01_2023_01). It was conducted in accordance with the Declaration of Helsinki. Participants gave informed consent before the experiment began. They were informed that the experiment involved seeing a video depicting verbal and physical harassment. They were asked not to proceed with the experiment if they felt uncomfortable with this. At the end of the experiment, participants were debriefed that the video depicting the crime had been staged.

Materials and Procedure

We used the same materials and procedure as Mayer et al. (2024, Experiment 2), as described above.

Results

The observed response frequencies are reported in Table 2. We used the same assumptions as in the reanalysis reported above to arrive at the base model. The base model fit the data, $G^2(2) = 3.44$, $p = .179$. Parameter b was estimated to be .04 (SE = .01). Parameter estimates for culprit-presence detection (dP), culprit-absence detection (dA), and guessing-based selection (g) are displayed as a function of age group in Panels D, E, and F of Figure 2, respectively.

Table 2
Response Frequencies in the Three Age Groups

Lineup type	Age group: Young adult	Young–old adult	Old–old adult
Culprit-present lineups			
Culprit identifications	399 (.39)	312 (.31)	233 (.23)
Filler identifications	391 (.38)	484 (.48)	575 (.57)
False lineup rejections	230 (.23)	208 (.21)	194 (.19)
Culprit-absent lineups			
Innocent-suspect identifications	144 (.14)	154 (.15)	147 (.15)
Filler identifications	481 (.47)	540 (.54)	636 (.63)
Correct lineup rejections	395 (.39)	310 (.31)	219 (.22)

Note. Observed response frequencies (proportions in parentheses) as a function of age group.

Consistent with the results of the reanalysis of the data of Mayer et al. (2024, Experiment 2) reported above, parameter dP which represents the probability of culprit-presence detection decreases with age, as can be seen in Panel D of Figure 2. The probability of culprit-presence detection differed significantly between young adults and young–old adults, $\Delta G^2(1) = 17.07$, $p < .001$, and between young–old adults and old–old adults, $\Delta G^2(1) = 17.78$, $p < .001$.

Descriptively, the pattern is the same for parameter dA which represents culprit-absence detection: As shown in Panel E of Figure 2, the probability of culprit-absence detection decreases with increasing age. However, the descriptive difference between the young adults and the young–old adults was not statistically significant, $\Delta G^2(1) = 0.48$, $p = .490$, and neither was the descriptive difference between the young–old adults and the old–old adults, $\Delta G^2(1) = 2.94$, $p = .087$.

As in the reanalysis of the data of Mayer et al. (2024, Experiment 2) reported above, parameter g which represents the probability of selecting a person from a lineup based on guessing increases with increasing age, as shown in Panel F of Figure 2. The probability of guessing-based selection differs significantly between young adults and young–old adults, $\Delta G^2(1) = 7.29$, $p = .007$, and between young–old adults and old–old adults, $\Delta G^2(1) = 5.10$, $p = .024$.

Discussion

The results of the novel experiment, which was specifically conducted for the purpose of examining age-related differences in the cognitive processes underlying lineup performance, are highly similar to those obtained in the reanalysis of the data of Mayer et al. (2024, Experiment 2): The probability of culprit-presence detection decreases with age. Descriptively, the probability of culprit-absence detection decreases with age as well, but the differences among the age groups were not statistically significant in the novel experiment, in contrast to the difference between young to middle-aged adults and young–old adults in the reanalysis of the data of Mayer et al. (2024, Experiment 2). It is possible that age-related differences in culprit-absence detection exist, but they may be very small and only robustly detectable in statistical tests with a particularly high sensitivity. Another pattern that was clearly replicated was that the probability of guessing-based selection increases with age. In essence, the results of the novel experiment lead to the same overall conclusion as the reanalysis: The contribution of memory-based processes to lineup responses decreases with increasing age whereas the contribution of a nonmemory-based guessing process increases.

General Discussion

The present research serves to examine age-related differences in the cognitive processes underlying observable eyewitness responses to lineups. To this end, we performed a model-based analysis of age-related differences in two large data sets. Using the 2-HT eyewitness identification model, we first reanalyzed data originally collected for a different purpose by Mayer et al. (2024, Experiment 2). Second, we analyzed data from a novel experiment that was run specifically to test whether the results on age differences obtained in the reanalysis of the data of Mayer et al. (2024, Experiment 2) are robust and can be confirmed in an independent study. In both cases, we distinguished not only between younger and older adults—as was done in most previous studies on age-related differences in lineup performance (Havard & Memon, 2009; Humphries et al., 2024;

Memon & Gabbert, 2003a, 2003b; Memon et al., 2003; Nyman et al., 2025; Pica & Pozzulo, 2018; Rose et al., 2005; Searcy et al., 1999; Wilcock & Bull, 2010; Wilcock et al., 2007; D. B. Wright & Stroud, 2002; Wylie et al., 2015)—but between younger adults (young to middle-aged in the reanalysis, young in the novel experiment) and young–old adults and between young–old adults and old–old adults. This was done because the distinction between young–old adults and old–old adults has become common practice in research on adult cognitive development as there are appreciable performance differences between these groups in various cognitive domains (e.g., Borella et al., 2007; Davis et al., 2003; Henry et al., 2015; Schmitter-Edgecombe & Simpson, 2001; Scogin et al., 1994; A. M. Wright & Holliday, 2007).

The results obtained from the analyses of both data sets are largely consistent. Overall, the contribution of memory-based processes to observable eyewitness responses decreases with age. There is clear evidence of an age-related decline in culprit-presence detection. In contrast, the contribution of guessing-based selection to observable eyewitness responses increases with age. The decrease in memory-based detection and the increase in guessing-based selection with advancing age may be considered problematic because only the memory-based responses to lineups hold evidentiary value while guessing-based responses do not. Although the lineups were challenging for all age groups (see Tables 1 and 2 and Figure 1), the age-related differences in the cognitive processes underlying eyewitness responses observed in young–old adults, and even more so in old–old adults, highlight that there may be particular difficulties in obtaining valid testimonies from eyewitnesses belonging to these groups.

How the cognitive processes jointly determine observable eyewitness responses is specified in the 2-HT eyewitness identification model. While there is obviously no one-to-one mapping of the cognitive processes to observable eyewitness responses, it is possible to loosely relate the present process-based findings to earlier findings at the level of response rates. For instance, the age-related decline in the probability of culprit-presence detection is consistent with results showing lower rates of correct culprit identifications in older compared with younger adults (Colloff et al., 2017; Erickson et al., 2016; Fitzgerald & Price, 2015; Havard & Memon, 2009; Humphries et al., 2024; Memon & Gabbert, 2003b; Rose et al., 2005; Sporer & Martschuk, 2014; D. B. Wright & Stroud, 2002; Wylie et al., 2015). The age-related increase in the probability of guessing-based selection may be related to lower rates of lineup rejections (Erickson et al., 2016; Memon & Gabbert, 2003a; Rose et al., 2005; Sporer & Martschuk, 2014) and higher rates of false innocent-suspect and filler identifications in older compared with younger adults (Pica & Pozzulo, 2018; Wilcock & Bull, 2010).

However, in some studies, no evidence for lower rates of correct culprit identification in older compared with younger adults was found (Key et al., 2015; Memon & Gabbert, 2003a; Memon et al., 2003; Nyman et al., 2025; Wilcock & Bull, 2010). This inconsistency may arise from several factors, including variability in procedures across studies, differences in sample sizes, variations in the age limits used to define age groups, and the fact that our study specifically focused on old–old adults, representing the extreme end of the age spectrum. Another key distinction between our present study and previous studies is the level of analysis: Whereas previous studies were focused on observable responses, we analyzed the underlying cognitive processes. This distinction is important because our findings indicate that the age-related decline in correct culprit-presence detection across older age is accompanied by an age-related increase in guessing-based selection. Since increases in guessing-based selection increase the likelihood of choosing someone from the lineup, they can lead to more culprit identifications, partially offsetting the effect of the decline in culprit-presence detection at the level of observable responses. As a result, the detection of age-related differences may succeed more readily in analyses at the level of cognitive processes than in analyses at the level of observable responses.

Our results align well with research aimed at investigating face recognition memory and recognition memory in general. For instance, Fraundorf et al. (2019) and Martschuk and Sporer (2018) reported that older adults were less likely to correctly indicate that a previously seen item (e.g., a face) had been presented before but more likely to falsely indicate that a previously unseen item had been presented before than younger adults. This pattern relates well to our finding of reduced probabilities of culprit-presence detection and increased probabilities of guessing-based selection in older compared with younger adults. Possible reasons for this age-related decline in recognition performance may include reduced processing resources which could cause lower probabilities of culprit-presence detection by impeding face encoding and retrieval (Martschuk & Sporer, 2018; Salthouse, 1996). Additionally, deficits in binding different aspects of items together, such as elements of faces and episodes (Chalfonte & Johnson, 1996; Kilb & Naveh-Benjamin, 2007), and an increased reliance on gist information (Koutstaal & Schacter, 1997) in older adults compared with younger adults could contribute to a decline in culprit-presence detection in older compared with younger adults. Moreover, the increase in guessing-based selection in older compared with younger adults fits well with results indicating that older adults show increased false remembering in the remember-know paradigm in comparison to younger adults (McCabe et al., 2009).

In the 2-HT eyewitness identification model, two types of memory-based processes contributing to observable eyewitness responses are specified: culprit-presence detection and culprit-absence detection. Age-related differences in the probability of culprit-presence detection were found to manifest more robustly than age-related differences in the probability of culprit-absence detection. Given that the estimates of parameter *dA* in the present study were relatively low (see Figure 2), the question may arise whether culprit-absence detection is a relevant process at all. A possible answer to this question begins by noting that in the data used for the reanalysis parameter *dA* is significantly above zero for the young to middle-aged adults, $\Delta G^2(1) = 24.47$, bootstrapped $p < .001$, and the young–old adults, $\Delta G^2(1) = 3.98$, bootstrapped $p = .030$, but not for the old–old adults, $\Delta G^2(1) = 0.12$, bootstrapped $p = .374$. The same is true for the novel experiment in which parameter *dA* is significantly above zero for the young adults, $\Delta G^2(1) = 8.80$, bootstrapped $p = .004$, and the young–old adults, $\Delta G^2(1) = 6.55$, bootstrapped $p = .002$, but not for the old–old adults, $\Delta G^2(1) = 0.23$, bootstrapped $p = .334$. For these tests, we relied on the parametric bootstrap procedure implemented in multiTree (Moshagen, 2010) to obtain an estimate of the *p* value from a simulated distribution because the null hypothesis implies a parameter value at the boundary of the parameter space (Klauer & Oberauer, 1995; Schmidt et al., 2023). The results of these tests may be taken to indicate that culprit-absence detection is a relevant process for all age groups except the old–old adults. Participants in the old–old group were unable to detect the absence of the culprit in culprit-absent lineups, at least under the conditions implemented in the experiments we report on here. These results underline the importance of the distinction between culprit-presence detection and culprit-absence detection, as this insight would have remained hidden had the memory-based processes been combined into a single measure.

The present studies are among the few studies (e.g., Scogin et al., 1994) on age-related differences in eyewitness performance in which a distinction is made between young–old adults and old–old adults. It is now clear that this distinction, which has proven to be useful in other areas of memory-related research (e.g., Aslan & Bäuml, 2013; Borella et al., 2007; Davis et al., 2003; Henry et al., 2015; Schmitter-Edgecombe & Simpson, 2001; Schnitzspahn & Kliegel, 2009), also contributes to a gain in knowledge in eyewitness-memory research. Specifically, the present analyses have revealed significant age-related differences between these groups in the processes of culprit-presence detection and guessing-based selection. Furthermore, culprit-absence detection was found to be nonexistent in old–old adults but existent in young–old adults. Obviously, important information would have been lost had we aggregated all adults over the age of, for example, 60 into a single group of old adults. Researchers as well as practitioners should bear this in mind when addressing questions related to age-related differences in eyewitness memory.

Conclusion

The aim of the present research was to contribute to a deeper understanding of age-related differences in eyewitness performance. Using the 2-HT eyewitness identification model to measure age-related differences in the cognitive processes underlying observable eyewitness responses, it has been shown that culprit-presence detection decreases with age. Culprit-absence detection consistently declines with age at a descriptive level, but statistical tests of age-related differences in culprit-absence detection have not always been statistically significant. By contrast, the probability of guessing-based selection has been consistently shown to increase with age. This shift from memory-based detection to guessing-based selection highlights potential challenges that age-related differences in the cognitive processes underlying eyewitness responses pose for the validity of eyewitness testimony.

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Received November 18, 2024
Revision received May 9, 2025
Accepted May 11, 2025 ■

Article submitted for publication

Article 3

This article includes Experiment 2.

Mayer, C., Bell, R., Menne, N. M., Lichtenhagen, U., Therre, A., Philippsen, A., & Buchner, A. (2025). Requiring fast rather than slow responses increases guessing-based selections without improving culprit-presence detection in lineups. *Manuscript submitted for publication*.

Requiring fast rather than slow responses increases guessing-based selections without improving culprit-presence detection in lineups

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We have no known conflict of interest to disclose.
The research project reported in this article was supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)—BU 945/10-2, project number 456214986.

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Abstract

Building on previous findings that response latency is a postdictor of the likelihood that a selection from a lineup is correct, here we tested the pragmatic question of whether instructing eyewitnesses to respond fast rather than slowly would improve the detection of the presence of the culprit in a lineup. To this end, we conducted a large-scale online experiment. In a fast-response condition, participants were instructed to respond spontaneously to lineups after a short temporal interval of seeing the lineup members. In a slow-response condition, participants were instructed to respond deliberately after a long temporal interval of seeing the lineup members. To measure the effects of the experimental manipulation of fast versus slow responding on the cognitive processes underlying eyewitness responses to lineups, the well-validated two-high threshold eyewitness identification model was used. The probability of culprit-presence detection was equivalent in the fast-response and slow-response conditions. In contrast, the probability of guessing-based selection was higher when participants were instructed to respond fast than when they were instructed to respond slowly. Thus, the present results suggest that eyewitnesses should not be instructed to respond fast rather than slowly because doing so may increase guessing-based selections without improving culprit-presence detection.

Keywords: Two-high threshold eyewitness identification model, eyewitness identification, police lineups, response latency

There is substantial evidence of a correlational relationship between response latency and the likelihood that a selection from a lineup is correct: Laboratory research has shown that participants who select a lineup member faster are more likely to select the culprit rather than a filler or the innocent suspect than eyewitnesses who take longer to make a selection [1-4] and that correct identifications of the culprit occur faster than incorrect selections of a filler or the innocent suspect [2, 5-15]. Data from real world lineups support this, showing that eyewitnesses who respond faster are more likely to select the suspect than eyewitnesses who take longer to respond [16] and that suspect identifications occur faster than filler selections [17]. By contrast, response latency appears to be unrelated to the likelihood that the rejection of a lineup is correct [3, 5, 8-13, 18]. In the research referred to above, response latency has typically been treated as an estimator variable, that is, a factor that may be indicative of eyewitness performance but is not under the control of the criminal justice system [19]. From this perspective, faster responses may reflect better memory without necessarily implying that fast responding causally increases the probability that an eyewitness will detect the presence of the culprit in the lineup. However, response latency could also be viewed as a system-dependent variable, in that it could be influenced by factors under the control of the lineup administrators, such as pre-lineup instructions that encourage participants to respond faster or slower. Therefore, the central question of the present research is whether, by treating response latency as a system variable, inducing faster rather than slower responding can improve culprit-presence detection. If so, simple procedural modifications, such as encouraging fast responses, could provide a pragmatic and easy-to-implement approach to improve lineup practice.

At first glance, it may seem unlikely that encouraging faster rather than slower responding would improve culprit-presence detection. This skepticism follows from the well-established speed-accuracy tradeoff [20], which could be interpreted to suggest that encouraging faster rather than slower responses may negatively affect the cognitive processes underlying lineup responses. Nevertheless, one might hypothesize that face recognition represents an exception to this principle. Specifically, it is conceivable that face-recognition mechanisms involved in fast responses may be more effective for culprit-presence detection than those involved in slow responses. For instance, eyewitnesses who respond faster may rely on a recognition signal that arises spontaneously—sometimes described as a "pop-out" effect [e.g., 4, 21, 22]. By contrast, eyewitnesses who respond more slowly may engage in deliberate feature-by-feature comparisons of all lineup members, a strategy known to be suboptimal for face recognition [15]. In support of this possibility, Dunning and Stern [23] found that participants who reported making more spontaneous responses also made faster responses and were more likely to select the culprit than those who reported making more deliberative responses. However, the relationship between spontaneous or deliberate responding and the likelihood that the selection from a lineup is correct has not been consistently replicated. Some researchers have found such a relationship [4, 24] whereas others have not [10, 14]. Thus, the pragmatic aim of the present experiment was to test whether instructing participants to respond fast rather than slowly affects their ability to detect the presence of the culprit in lineups.

Although past research gives reason to examine whether instructing eyewitnesses to respond fast rather than slowly is beneficial for detecting the presence of the culprit in a lineup, potential adverse effects must also be considered. For instance, requiring fast responses gives participants less time to align their responses with task instructions, including the instruction to reject the lineup when the culprit is not present, which could increase guessing-based selection (see Figure 1). Highlighting this risk, Brewer et al. (2000)[21] found that requiring participants to respond fast rather than slowly was not beneficial: In their study, only culprit-present lineups were shown and the duration of lineup presentation was varied between 2.5, 5, 20 or 40 seconds. After the lineup had disappeared, participants were required to respond immediately. Participants were less likely to correctly select the culprit and more likely to incorrectly select a filler when the lineup was presented for a shorter duration (2.5 or 5 seconds) than when it was presented for a longer duration (20 or 40 seconds). Although no culprit-absent lineups were used in this study—making it impossible to fully identify the processes underlying the lineup responses—it is conceivable that the increase in filler selections may reflect a rise in guessing-based selection under time pressure. Thus, any proper investigation of the effects of fast versus slow responses in lineups should also include a measure of guessing-based selection.

The parallel measurement of both culprit-presence detection and guessing-based selection is possible with the two-high threshold (2-HT) eyewitness identification model [25, 26]. The 2-HT eyewitness identification model belongs to the broader class of multinomial processing tree models which are commonly used to estimate the probabilities of latent cognitive processes from observable responses [27-29]. Comprehensive tutorials [30] and user-friendly software [31] make this class of models highly accessible. A key advantage of the 2-HT eyewitness identification model is that its parameters which represent the cognitive processes underlying observable responses to lineups have been rigorously validated. Validation has been conducted in both a series of experiments explicitly designed for this purpose [26] and in a series of reanalyses [25] of data collected in various laboratories around the world using various mock-crime scenarios, face stimuli and lineup procedures [32-39]. Moreover, the model's usefulness for conducting lineup research has been demonstrated repeatedly [40-46].

With the 2-HT eyewitness identification model, it is possible to measure the probabilities of four separate cognitive processes that underlie the observable responses to lineups: culprit-presence detection, culprit-absence detection, biased suspect selection in unfair lineups and guessing-based selection. To determine these probabilities, the model takes into account all observable response categories in lineups, namely culprit identifications, innocent-suspect identifications, false and correct lineup rejections and filler selections in both culprit-present and culprit-absent lineups. An illustration of the model is depicted in Figure 1. The joint multinomial model is illustrated in the form of two trees: The upper tree depicts the processes that may occur in a culprit-present lineup while the lower tree depicts the processes that may occur in a culprit-absent lineup.

In a culprit-present lineup, the presence of the culprit is detected with probability dP, resulting in a correct culprit identification. The presence of the culprit is not detected with the complementary probability $1 - dP$, in which case two non-detection-based processes determine the eyewitness's response. Biased suspect selection refers to the identification of a suspect due to eyewitness noticing that the suspect stands out from the fillers in an unfair lineup. Biased selection occurs with probability b, leading to a culprit identification. Parameter b captures lineup unfairness and thereby allows for the other model parameters to be determined without being contaminated by lineup unfairness. No biased suspect selection occurs with the complementary probability $1 - b$. Then, a lineup member may still be selected based on guessing with probability g. In this case, selection is considered random, implying that the probabilities of culprit and filler identifications depend on the lineup size. With probability 1 ÷ lineup size (1 ÷ 6 in six-person lineups), the culprit is identified. With the complementary probability 1 – (1 ÷ lineup size), a filler is identified. No guessing-based selection occurs with the complementary probability 1 – *g*, resulting in a lineup rejection.

In a culprit-absent lineup, the absence of the culprit is detected with probability *dA*, leading to a correct rejection of the lineup. The absence of the culprit is not detected with the complementary probability 1 – *dA*, in which case the same non-detection-based processes follow as in a culprit-present lineup. This is because, when neither the presence nor the absence of the culprit is detected, culprit-present and culprit-absent lineups are indistinguishable to the eyewitness. However, in culprit-absent lineups the non-detection-based processes may lead to the identification of the innocent suspect instead of the culprit.

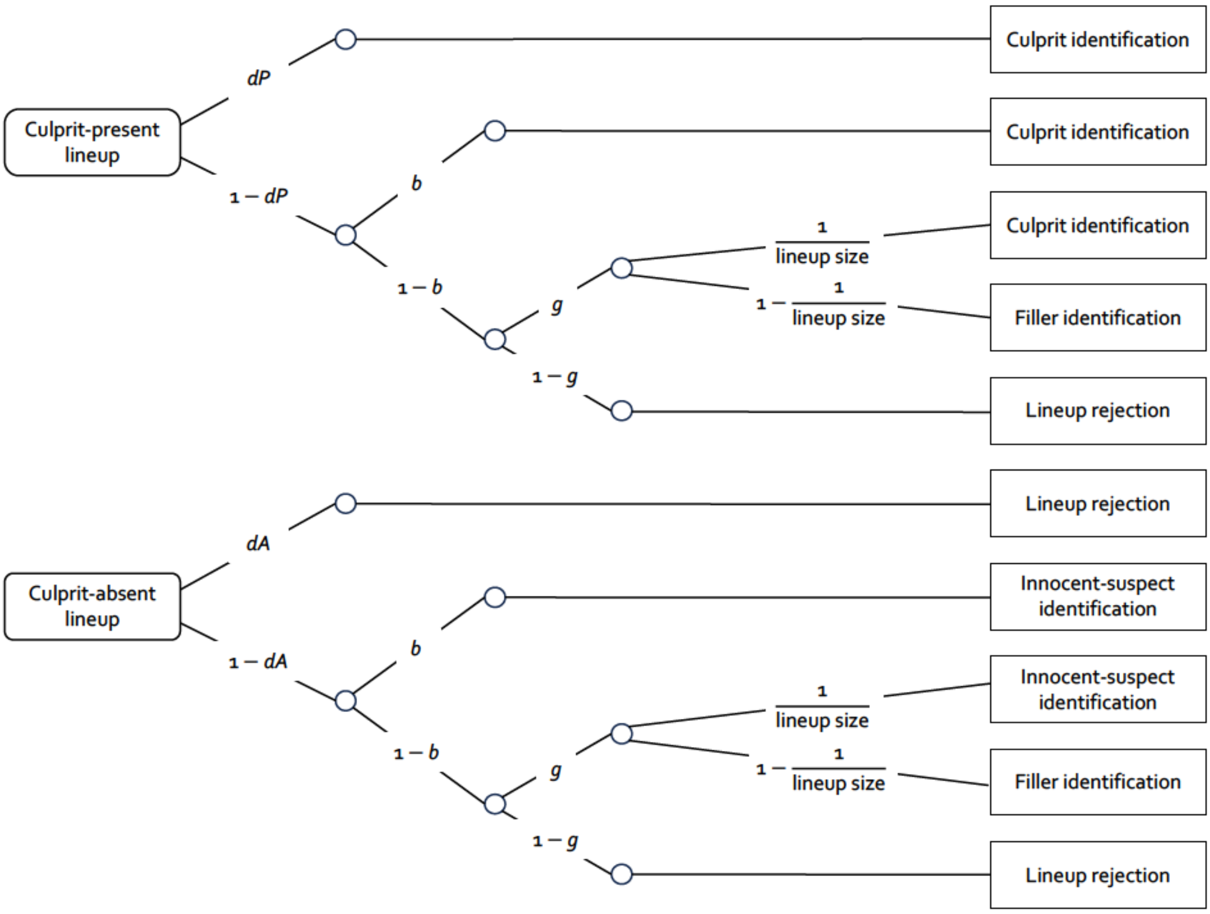

Figure 1. Illustration of the 2-HT eyewitness identification model. The rounded rectangles on the left represent the two different types of lineups presented: culprit-present lineups and culprit-absent lineups. The rectangles on the right represent the categories of observable responses. The letters along the branches represent the probabilities of the latent cognitive processes postulated in the model: dP: culprit-presence detection; b: biased suspect selection; g: guessing-based selection; dA: culprit-absence detection. Guessing-based selection results in the selection of the (guilty or innocent) suspect with the sampling probability given by the reciprocal of the lineup size.

The pragmatic purpose of the present experiment was to test whether instructing eyewitnesses to respond fast rather than slowly improves the detection of the presence of the culprit in lineups. To experimentally manipulate response latency, a fast-response condition was compared to a slow-response condition. In the fast-response condition, participants were instructed to respond spontaneously after a short temporal interval (3 seconds); in the slow-response condition, participants were instructed to respond deliberatively after a long temporal interval (20 seconds). If fast compared to slow responses lead participants to rely on recognition mechanisms that are more favorable for detecting the presence of the culprit [4, 22-24], then the culprit-presence-detection parameter *dP* should be significantly higher in the fast-response condition than in the slow-response condition. However, if instructing participants to respond fast rather than slowly reduces participants' inclination to align their responses with the instructions to reject the lineup when detection fails, then the guessing-based selection parameter *g* should be higher in the fast-response condition than in the slow-response condition.

Method

In the present experiment, we used the same staged-crime videos, suspect photos, filler photos, lineup design and—with the exception of the response-latency manipulation—the same procedure as in previous studies in which the 2-HT eyewitness identification model was applied to measure the processes underlying eyewitness responses [26, 40-46]. We repeat their description here for convenience.

Participants

Participants were recruited and compensated through Bilendi, an ISO 20252-certified research panel provider (https://www.bilendi.de). Of the datasets of participants who responded to the socio-demographic questions at the beginning of the experiments, 325 datasets were excluded because the participants did not complete the experiment or withdrew the consent to the use of their data, 41 datasets were excluded because the participants had seen the staged-crime video more than once, 18 datasets were excluded because the participants failed the attention check (see Procedure section) and two datasets were excluded because the participants, on average, took more than an hour to respond to each lineup.

Consequently, the final sample comprised 1503 participants from a wide range of educational backgrounds, of which 744 identified as female and 759 identified as male. The mean age of the participants was 52 years (*SD* = 14). Participants were randomly assigned to one of two experimental conditions: A total of 750 participants were assigned to the fast-response condition and 753 participants were assigned to the slow-response condition. A sensitivity analysis conducted with G*Power [47] showed that, given error probabilities of $\alpha = \beta = .05$ (and thus a statistical power of $1 - \beta = .95$), a sample size of $N = 1503$, four lineups per participant and $df = 1$ for the comparison of the culprit-presence detection parameter dP (or the guessing-based selection parameter g) between the fast-response condition and the slow-response condition, effects as small as $w = 0.05$ could be detected.

Ethics statement

The experiment is part of a series of experiments that were approved by the ethics committee of the Faculty of Mathematics and Natural Sciences at Heinrich Heine University Düsseldorf. It was conducted in accordance with the Declaration of Helsinki. In both experiments, participants gave informed consent prior to participation. Participants were informed that the experiments involved seeing a video depicting verbal and physical harassment. They were asked not to proceed with the experiment if they felt uncomfortable imagining to watch such a video. At the end of the experiments, participants were informed that the video showing the crime had been staged.

Materials

Staged-crime videos

Participants were shown one of two staged-crime videos. In both videos, four white, young, male culprits wearing fan clothing of the German soccer club FC Bayern München assaulted a white, young male victim wearing a fan clothing of the rivaling German soccer club Borussia Dortmund. Including four culprits in the staged-crime videos allowed us to obtain four lineup responses per participant, thereby enhancing the statistical sensitivity of our analyses without compromising ecological validity as a substantial proportion of crimes involve multiple culprits [48-50]. Both videos showed the same actions in the same sequence and timing, lasted for about 130 seconds and were displayed at a resolution of 885 × 500 pixels.

The only difference between the videos was the actors portraying the culprits and the victim. The actors were selected so that the actor portraying a specific culprit in one video resembled his counterpart in the other video. Analogously, the victims in the videos resembled each other. Both videos clearly showed the faces of all culprits, including their frontal views.

Lineups

Participants responded to four lineups, two culprit-present lineups and two culprit-absent lineups. Each lineup consisted of one suspect and five fillers. The crossed-lineup procedure [25, 26, 40-45] was used to manipulate culprit presence. In the culprit-present lineups, the suspect was one of the culprits from the video that the participants had seen. In the culprit-absent lineups, the suspect was one of the culprits from the video that the participants had not seen. For example, if a participant had seen Video A, the culprit-present lineups contained two randomly selected culprits, say Culprit 1 and 2, from Video A and the culprit-absent lineups contained Culprit 3 and 4 from Video B. We used the crossed-lineup procedure to ensure that there were no systematic differences the culprits and the innocent suspects and that the photos of the culprits and innocent suspects differed to the same degree from the filler photos. The filler photos were selected from the Center for Vital Longevity Face Database [51]. The photos depicted white men aged between 18 and 29 years. The fillers were selected to resemble the culprits in terms of body shape, hair color and hairstyle (for an illustration of the lineups, see [26]). This approach reflects typical police practice in which the photo of the suspect, whose guilt or innocence has not yet been determined, is derived from a different source (e.g. social media) than the filler photos which are usually taken from face databases [52]. The suspect and filler photos were adjusted for uniform lighting and face size and presented at a resolution of 142 × 214 pixels.

Procedure

The experiment was conducted online using SoSciSurvey [53]. After responding to a socio-demographic questionnaire, participants watched one of the two staged-crime videos described above. Which of the two videos was shown was determined at random. After the video had ended, participants were asked to respond to an attention-check question: Out of ten alternatives, participants had to correctly select “soccer fans” as the group of people shown in the video. Participants who failed the attention check were excluded from the experiment.

In the lineup instructions, participants were asked to identify the culprits from the video and informed that they would see multiple lineups. They were instructed that the lineups might or might not contain a culprit and that it was equally important to identify the culprit when present as it was to reject the lineup when no culprit was present. They were informed that they would initially see only the photos. The rest of the instructions differed between the conditions. Participants in the fast-response condition received the following instructions (originally in German):

> "Spontaneous responses are correct more often than responses that are overthought. Therefore, you can respond after just 3 seconds."

Participants in the slow-response condition received the following instructions (originally in German):

> "Responses that are thoroughly deliberated are correct more often than responses that are rushed. Therefore, you can respond only after 20 seconds."

Then the four lineups—one for each culprit in the staged-crime video—were shown in a randomized order. Two of the lineups were randomly determined to be culprit-present and two to be culprit-absent. Before each lineup, participants were shown a reminder, depending on the condition: Participants in the fast-response condition received the following reminder (originally in German):

> "Respond spontaneously. Spontaneous responses are correct more often than responses that are overthought. Therefore, you can respond after just 3 seconds."

Participants in the slow-response condition received the following reminder (originally in German):

> "Respond deliberatively. Deliberate responses are correct more often than responses that are rushed. Therefore, you can only respond after 20 seconds."

At the start of each lineup, the photos of six lineup members were displayed in a single row. The positions of the lineup members in the lineup were randomized. After 3 seconds in the fast-response condition or 20 seconds in the slow-response condition, the response options were shown. Beneath each of the six photos appeared a button labeled "Yes, was present" which participants could click to identify a lineup member. Additionally, a "No, none of these persons was present" button appeared to the right of the lineup, allowing participants to reject the lineup. Participants were required either identify a lineup member or to reject the lineup before they could click the "Next" button to proceed. In both conditions, the lineup remained visible until a response was given, ensuring that participants had sufficient time to view the faces before indicating their response. Measured from the moment the lineup became visible until participants continued to the next page, response times were significantly lower in the fast-response condition (M = 12 seconds, SD = 13) than in the slow-response condition (M = 33 seconds, SD = 72), $t(6010) = -15.66$, $p < .001$. Prior to each lineup, except for the first one, participants had to wait 20 seconds in the fast-response condition or 3 seconds in the slow-response condition before proceeding to the next lineup. During this delay, the message "Your response is being processed. This can take a moment. The experiment will continue in x seconds" was displayed on the screen. This was intended to keep the delay between the staged-crime videos and each of the four lineups consistent across conditions. After the final lineup, participants were debriefed and thanked for their participation.

Results

Goodness-of-fit tests and parameter estimates were obtained using multiTree [31]. The observed response frequencies are displayed in Table 1. Two instances of the 2-HT eyewitness identification model depicted in Figure 1 were necessary to analyze the data: one for the fast-response condition and one for the slow-response condition. Given that each lineup consisted of six lineup members, the constant 1 ÷ *lineup size* was set to 0.16667, an approximation to 1 ÷ 6. To establish a testable base model, the same restrictions as in previous research [40, 42, 45] were applied. Specifically, as the same sets of suspects and fillers were used in both conditions, there is no apparent reason as to why lineup fairness should differ between the conditions. In addition, the experimental manipulation used in this experiment is clearly distinct from those that influence the probability of detecting the absence of the culprit [25, 26]. Parameters dA and b were therefore set to be equal in both conditions. This base model fit the data, $G^2(2) = 1.42$, $p = .493$, indicating that these restrictions are compatible with the data. Parameter dA was estimated to be 0.01 (SE = 0.03) and parameter b was estimated to be 0.04 (SE = 0.01).

	Fast response	Slow response
Culprit-present lineups		
Culprit identifications	509	508
Filler identifications	434	415
False lineup rejections	557	583
Culprit-absent lineups		
Innocent-suspect identifications	179	171
Filler identifications	595	526
Correct lineup rejections	726	809

Table 1. Observed response frequencies in the fast-response and slow-response condition.

The estimates for culprit-presence-detection parameter *dP* and guessing-based-selection parameter *g* are presented in Figure 2. Using the 2-HT eyewitness identification model, it is possible to test hypotheses about the cognitive processes directly at the level of the parameters that represent the cognitive processes. To this end, the parameters representing the cognitive process of interest are set to be equal in the fast-response condition and the slow-response condition. If a model with such a restriction fits the observed data significantly worse than the base model without the restriction, it can be concluded that the probability of the cognitive process differs between the conditions. Restricting the culprit-presence-detection parameter *dP* to be equal in both conditions did not significantly decrease the model fit, $\Delta G^2(1) = 0.03$, $p = .860$. Therefore, it can be concluded that culprit-presence detection did not differ as a function of whether participants were instructed to respond fast or slowly. In contrast, restricting the guessing-based-selection parameter *g* to be equal in both conditions significantly reduced the model fit, $\Delta G^2(1) = 8.49$, $p = .004$. The probability of guessing-based selection was higher when participants were instructed to respond fast than when they were instructed to respond slowly.

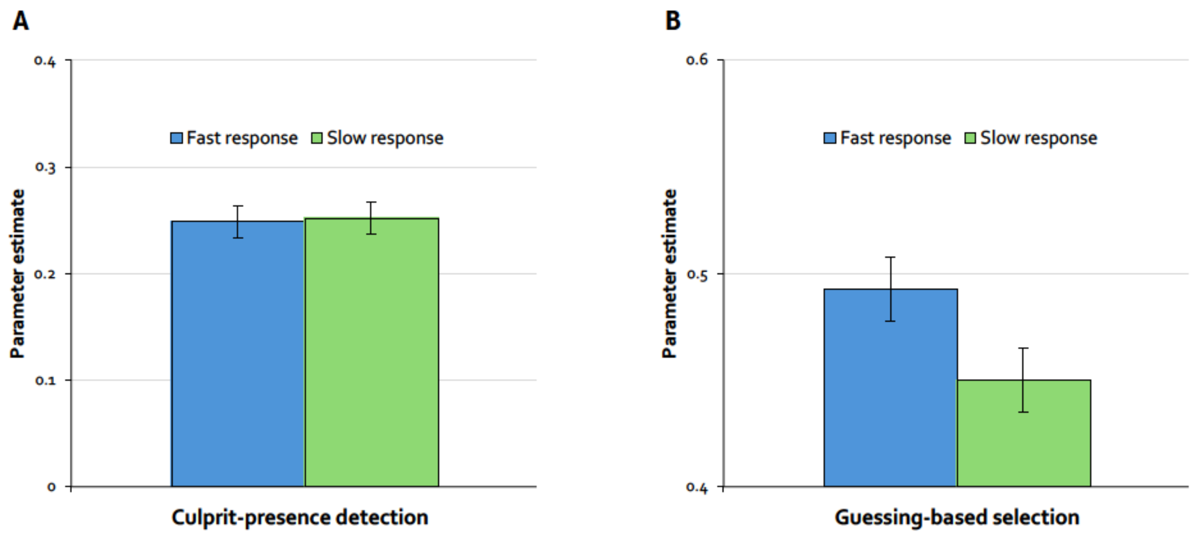

Figure 2. Estimates of the culprit-presence-detection parameter *dP* (Panel A) and the guessing-based-selection parameter *g* (Panel B) in the fast-response and slow-response conditions. Error bars represent standard errors.

Discussion

The present study addresses the pragmatic question of whether instructing eyewitnesses to provide fast rather than slow responses can improve the detection of the presence of the culprit in the lineup. To test this question, we conducted an experiment in which response latency was experimentally manipulated: In the fast-response condition, participants were instructed to respond spontaneously after a short temporal interval and in the slow-response condition, participants were instructed to respond deliberatively after a longer interval. In addition to identifying potential benefits of fast versus slow responses on culprit-present detection, it was important to assess possible adverse effects of this manipulation on guessing-based selection. When responding fast, eyewitnesses might have less time to align their response with task instructions, particularly the instruction to reject the lineup when the culprit is not detected. Therefore, we tested whether instructing eyewitnesses to provide fast versus slow responses increases guessing-based selection.

To test both hypotheses within a single measurement model, we used the well-validated 2-HT eyewitness identification model [25, 26] to separately measure the cognitive processes underlying eyewitness responses to lineups, including both culprit-presence detection and guessing-based selection. Instructing participants to respond fast rather than slowly did not improve culprit-presence detection. A possible explanation may be that culprit-presence detection is primarily based on a fast recognition mechanism that arises spontaneously, for example through a pop-out effect [e.g., 4, 21, 22]. Given that the recognition process is already completed after a comparatively short temporal interval, additional time to process the faces in a deliberate manner can neither enhance nor impair culprit-presence detection. In contrast, the probability of guessing-based selection was higher when participants were instructed to provide fast rather than slow responses. This may be because faster, more spontaneous responding limits the time available to align responses with task instructions, particularly the instruction to reject the lineup when the culprit is not detected, which may cause higher rates of guessing-based selection (see Figure 1). Slower, more deliberate responding, in contrast, may allow participants to better reflect on the lineup instructions and reduce their reliance on guessing-based selection.

Based on these results, it cannot be recommended to instruct eyewitnesses to respond fast rather than slowly in real-world lineups. Importantly, the present study tested a specific causal hypothesis: whether inducing fast rather than slow responding improves culprit-presence detection. As such, the findings do not contradict other possible relationships of culprit-presence detection and response latency [54]. The present conclusions parallel those by Brewer et al. [21] who also experimentally manipulated response latency. Brewer et al. [21] found that participants were less likely to select the culprit and more likely to select a filler when the lineup was presented for a shorter duration than when it was presented for a longer duration. However, a direct comparison between the studies is difficult due to procedural differences. For instance, in the study by Brewer et al.[21], the lineup disappeared after a fixed presentation time whereas in the present experiment, the lineup remained visible until a response was made. Moreover, Brewer et al. [21] included only culprit-present lineups which precludes an analysis of the underlying processes such as culprit-absence detection and guessing-based selection. As such, the cognitive processes underlying their results remain unclear whereas in the present experiment guessing-based selection is identified as the main process affected by the response-latency manipulation.

In sum, the present results provide no reason to recommend instructing eyewitnesses to respond fast rather than slowly to lineups. Fast responding had no beneficial effect on culprit-presence detection and instead had the undesirable effect of increasing guessing-based selection. Therefore, the safest option for lineup practice may be to avoid pressuring eyewitnesses to make spontaneous, fast responses and instead to encourage them to take their time and to respond deliberatively. This conclusion aligns with the broader principle reflected in best-practice guidelines, which recommend minimizing pressure of any kind [55].

Funding

The research project reported in this article was supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)—BU 945/10-2, project number 456214986.

Author contribution

CM and NMM developed the experiment and implemented suggestions by RB, UL, AT and AB. CM collected the data and analyzed them, taking into account suggestions by RB, NMM, UL, AT, AP and AB. CM wrote the first draft of the manuscript. RB, NMM, UL, AT, AP and AB revised the manuscript. All authors gave final approval for publication.

Data availability statement

The data of the experiment are available at the project page of the Open Science Framework under https://osf.io/xzgvj/?view_only=022a4b0fed314cab90574a26555155d4.

Additional Information

The authors declare no competing interests.

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Declaration of the independent contribution

The present dissertation includes three articles, with four experiments and one reanalysis in total. Of these articles, two have been published and one has been submitted for publication in academic journals with an established peer-review process. In the following, I will elaborate how each author individually contributed to the articles. The majority of work was always carried out by the first author of the article.

Independent contribution to article 1

Publication: Mayer, C., Bell, R., Menne, N. M., & Buchner, A. (2024). Lineup position affects guessing-based selection but not culprit-presence detection in simultaneous and sequential lineups. *Scientific Reports*, *14*, Article 27642. https://doi.org/10.1038/s41598-024-78936-9

Study conception: I developed the experimental design of Experiments 3a and 3b with support from Raoul Bell, Nicola Marie Menne and Axel Buchner.

Implementation: I programmed and conducted Experiments 3a and 3b with feedback from Raoul Bell, Nicola Marie Menne and Axel Buchner.

Data analysis: I conducted the statistical analyses of Experiments 3a and 3b independently. Raoul Bell, Nicola Marie Menne and Axel Buchner reviewed their accuracy.

Manuscript: I prepared the manuscript independently, including an extensive literature review, the design of the figures and the composition and writing of the manuscript. Raoul Bell, Nicola Marie Menne and Axel Buchner provided feedback which I incorporated after a thorough review and subsequent consultation. I managed the peer-review process through the academic journal. During this process, I made revisions with support from Raoul Bell, Nicola Marie Menne and Axel Buchner.

Independent contribution to article 2

Publication: Mayer, C., Bell, R., Menne, N. M., Therre, A., Lichtenhagen, U., & Buchner, A. (2025). Evidence for age-related differences in culprit-presence detection and guessing-based selection in lineups. *Psychology and Aging*, Advance online publication. https://doi.org/10.1037/pag0000916

Study conception: I developed the experimental design of Experiment 1 with support from Raoul Bell, Nicola Marie Menne, Amelie Therre, Ulla Lichtenhagen and Axel Buchner.

Implementation: I programmed and conducted Experiment 1 with feedback from Raoul Bell, Nicola Marie Menne, Amelie Therre, Ulla Lichtenhagen and Axel Buchner.

Data analysis: I conducted the statistical analyses of the reanalysis and Experiment 1 independently. Raoul Bell, Nicola Marie Menne, Amelie Therre, Ulla Lichtenhagen and Axel Buchner reviewed their accuracy.

Manuscript: I prepared the manuscript independently, including an extensive literature review, the design of the figures and the composition and writing of the manuscript. Raoul Bell, Nicola Marie Menne, Amelie Therre, Ulla Lichtenhagen and Axel Buchner provided feedback which I incorporated after a thorough review and subsequent consultation. I managed the peer-review process through the academic journal. During this process, I made revisions with support from Raoul Bell, Nicola Marie Menne, Amelie Therre, Ulla Lichtenhagen and Axel Buchner.

Independent contribution to article 3

Article Submitted for Publication: Mayer, C., Bell, R., Menne, N. M., Lichtenhagen, U., Therre, A., Philippsen, A., & Buchner, A. (2025). Requiring fast rather than slow responses increases guessing-based selections without improving culprit-presence detection in lineups. *Manuscript submitted for publication.*

Study conception: I developed the experimental design of Experiment 2 with support from Raoul Bell, Nicola Marie Menne, Ulla Lichtenhagen, Amelie Therre, Ana Philippsen and Axel Buchner.

Implementation: I programmed and conducted Experiment 2 with feedback from Raoul Bell, Nicola Marie Menne, Ulla Lichtenhagen, Amelie Therre, Ana Philippsen and Axel Buchner.

Data analysis: I conducted the statistical analyses of Experiment 2 independently. Raoul Bell, Nicola Marie Menne, Ulla Lichtenhagen, Amelie Therre, Ana Philippsen and Axel Buchner reviewed their accuracy.

Manuscript: I prepared the manuscript independently, including an extensive literature review, the design of the figures and the composition and writing of the manuscript. Raoul Bell, Nicola Marie Menne, Ulla Lichtenhagen, Amelie Therre, Ana Philippsen and Axel Buchner provided feedback which I incorporated after a thorough review and subsequent consultation. I managed the peer-review process through the academic journal. During this process, I made revisions with support from Raoul Bell, Nicola Marie Menne, Ulla Lichtenhagen, Amelie Therre, Ana Philippsen and Axel Buchner.

Erklärung an Eides statt

Ich versichere an Eides statt, dass die Dissertation von mir selbständig und ohne unzulässige fremde Hilfe unter Beachtung der „Grundsätze zur Sicherung guter wissenschaftlicher Praxis an der Heinrich-Heine-Universität Düsseldorf" erstellt worden ist.

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Düsseldorf, 29. Juli 2025

Carolin Kristin Mayer