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MEMORY AND DECISION PROCESSES ON LINEUP IDENTIFICAIONS FOLLOWING MUGSHOT EXPOSURE

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MEMORY AND DECISION PROCESSES ON LINEUP IDENTIFICAIONS FOLLOWING MUGSHOT EXPOSURE

A DISSERTATION APPROVED FOR THE
DEPARTMENT OF PSYCHOLOGY

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TABLE OF CONTENTS

LIST OF TABLES vi

ABSTRACT vii

INTRODUCTION 1

METHOD 13

RESULTS 17

DISCUSSION 26

THEORETICAL DEVELOPMENT 29

GENERAL DISCUSSION 48

AUTHOR NOTES 53

REFERENCES 56

TABLES 63

APPENDIX A 72

APPENDIX B 73

LIST OF TABLES

1. Lineup composition for each condition 63
2. Proportion of lineup choices by condition 64
3. Source judgments for all conditions separated by type of lineup decision.....65
4. Proportion of lineup choices for mugbook choosers 66
5. Notation and model parameters 67
6. Parameter values for the perpetrator search data – choice included and choice not included.....68
7. Data, model predictions, and fit statistics for the perpetrator search choice included conditions 69
8. Data, model predictions, and fit statistics for the perpetrator search choice not included conditions 70
9. Data, model predictions, and fit statistics for the look alike condition.....71

ABSTRACT

The present study manipulated mugshot search task instructions to reveal when witnesses make commitment or familiarity based lineup errors. Additionally we examined the memory and decision making processes underlying these lineup choices using a computational model. In order to examine these processes, an extension of Clark's (2003) WITNESS model was developed – WITNESS-ME (ME for Mugshot Exposure). In support of previous research, we found a robust commitment effect. Commitment is due to strong encoding of the committed foil and the differentiation of that choice to the other lineup members. When participants were required to choose several foils that resembled the perpetrator from the mugbook (rather than searching for a single perpetrator), no differences in correct identification between the mugbook and no-mugbook control were found. We also found evidence for errors to due to conscious inference and source monitoring in all mugbook conditions. Modeling these data supported the hypothesis that witnesses are influenced by the number of plausible choices in the lineup and subsequently may adopt different strategies because of this. Theoretical and practical implications are discussed.

INTRODUCTION

Most theorizing about recognition memory assumes the simplest of decision mechanisms borrowed from signal detection: the generation of a scalar familiarity value and its comparison to a criterion (for a review of global matching models see Clark & Gronlund, 1996). Even more complex single-process memory (REM, Shiffrin & Steyvers, 1997) and dual process (e.g., Yonelinas 1999) theories include relatively simply decision mechanisms and fail to consider strategic factors (but see Malmberg, 2008). The simplicity of the experiments that are conducted to test these theories limit the strategies that individuals deploy. However, consideration of the use of memory to solve more complex problems, like those involving eyewitness identification or studying for a final exam, makes obvious that there is more to consider. For example, a decision criterion might vary during testing (e.g., Benjamin & Bawa, 2006; Brown, Steyvers, & Hemmer, 2007). Cognitive control can constrain retrieval so only sought after information is brought to mind (e.g., Jacoby, Shimizu, Daniels, & Rhodes, 2005). Benjamin (2008) reviewed evidence involving strategic influences at encoding, the strategic regulation of memory access, and the influence of postaccess decision processes. This memory as skilled cognition approach (see Benjamin & Ross, 2008) requires the joint consideration of memory and decision processes, an approach we take in our exploration of the domain of eyewitness identification.

Eyewitness identification is an ideal test bed for investigating the interaction of memory and decision processes. There are many different factors at work that affect the encoding, storage, and retrieval of eyewitness memories (e.g., Loftus 1979; Wells &

Olson, 2003). The present research focuses on retrieval and the factors that affect a lineup decision. The simple addition of allowing a participant the option of whether or not to choose from a lineup introduces flexibility regarding how a participant can deploy memory and decision processes. But various other factors also play a role, like the willingness to make a choice and the decision rules used.

Clark (2003) developed a computational model of lineup decision making in eyewitness identification, a model we will utilize in this paper. Goodsell, Gronlund and Carlson (2010) used Clark's WITNESS model to explore the effects of how the type of lineup (simultaneous or sequential) affects performance. They proposed decision and memory modifications to WITNESS that involved the shifting of the decision criterion and the improvement of a memory probe. The current study is conducted in the same spirit, with the focus on the effects of mugshot exposure on lineup identification accuracy.

Two real world cases set the backdrop for the current project. First, Ronald Cotton was convicted of rape and burglary and sentenced to life plus 54 years. The victim, Jennifer Thompson, was robbed and sexually assaulted. A few days after the crime, the police had Thompson view mugshots of individuals with a criminal record. She chose Ronald Cotton from the mugbook search. Cotton was arrested and later appeared in a lineup where Thompson again chose him. Cotton spent over 10 years in prison before being exonerated by DNA evidence. Interestingly, Thompson had an opportunity to see her actual assailant in a retrial after claims that Bobby Poole (the actual perpetrator) had confessed to the crime while in prison. Poole was brought before Thompson and she denied he was the one who attacked her.

The second case involved Anthony Woods who was convicted of rape, felonious restraint, and armed criminal action and sentenced to 25 years in prison. The victim, a 15-year old girl, was assaulted as she was walking to school. Following the assault, the police showed the victim hundreds of mugshots. Woods was among the photographs shown but was not selected. Later that day the victim saw Woods walking by her home and she identified him as the man who raped her. Woods spent 18 years in prison before being paroled, after which he sought legal assistance to prove his innocence. DNA testing excluded him as the perpetrator.

From these stories it is evident that a simple procedure designed to facilitate a police investigation (a mugshot search) can have dire consequences, not only for an innocent suspect but also for memory itself. The current study was designed to create situations in the lab similar to those of the Cotton and Woods cases. Participants view a mock crime, search through mugshot photos, and subsequently make a lineup identification. We are interested in the situation where people select someone from a mugshot search (like the Cotton case) and when they are exposed to someone in the mugshot search that they later see in the lineup (as in the Woods case).

The organization of the paper is as follows: We begin with a review of existing research on the mugshot exposure effect. This review will highlight two potential causes of lineup identification error – familiarity errors and commitment errors. The empirical goals of the paper are to explore the factors that give rise to these errors. The experiment we conducted investigated the extent to which differing task goals impact these errors. Finally, we will discuss our attempts to develop a computational model to account for our findings.

Police routinely employ mugshots in criminal cases involving eyewitnesses. Prior research has demonstrated the deleterious effects of such a practice. A recent meta-analysis (Deffenbacher, Bornstein, & Penrod, 2006) illustrated two key aspects regarding mugshot exposure. Specifically, eyewitnesses can mistakenly identify someone they viewed (but did not select) in a mugshot search in a subsequent lineup (known as a *transference or familiarity effect*) or they can identify someone from a lineup that they previously identified in a mugshot search (known as a *commitment effect*). Note that the case of Anthony Woods would be classified as a familiarity error and Ronald Cotton's case would be classified as a commitment error. We begin with familiarity errors.

Familiarity Errors

Familiarity effects have been demonstrated most commonly in studies involving bystander misidentification (Loftus, 1976; Read, Tollestrup, Hammersley, McFadzen & Christensen, 1990; Ross, Ceci, Dunning, & Toglia, 1994). In studies like these, participants are exposed to a perpetrator in one context and an innocent bystander in another context, who they subsequently mistakenly identify in an identification task. Mistaken identification has been attributed to one of three processes in this situation (see Phillips, Geiselman, Haghighi, & Lin, 1997). In *unconscious transference* (Loftus, 1976), an eyewitness misidentifies the bystander as the perpetrator because the eyewitness only remembers the perpetrator's context, forgetting the different context that included the bystander. In *conscious inference* (Read et al., 1990), participants can recall both the bystander and the perpetrator being present in both contexts, but infer they were the same person. A *source monitoring* error (Johnson, Hashtroudi, & Lindsey, 1993) is

when the eyewitness recalls both the perpetrator and the bystander but incorrectly attributes the role of the perpetrator to the bystander.

Phillips et al. (1997) investigated the boundary conditions surrounding these three processes. In their study, participants watched a video where a bystander and the perpetrator were viewed simultaneously within a scene (thus allowing a participant to realize that they were two different people) or in separate scenes (where the two could conceivably be confused). Phillips et al. found that in cases where the two had been viewed in different scenes, participants were able to identify correctly the perpetrator (*P* =.52) from a lineup that did not contain the bystander, but when the bystander was included in the perpetrator present lineup, the bystander was identified at a high rate (*P* = .72). Written descriptions indicated that participants believed the bystander to be the perpetrator. Thus, their results supported the *conscious inference* hypothesis. Phillips et al. (1997) concluded that witnesses store separate memory traces that are linked by a contextual tag and subsequently infer that the two are the same person. This finding will be important in the development of a formal memory model of mugshot exposure (discussed below).

A similar scenario could occur following mugshot exposure. One of the original studies demonstrating transference in a mugshot exposure study was Brown, Deffenbacher, and Sturgill (1977). In this study, participants were exposed to a target person passing out exams in their class. Two to three days later, participants viewed a series of 12 mugshots that included a photo of the target. Finally, after another four to five days, participants viewed a lineup that included the target as well as a photo of someone viewed in the mugshot phase (familiar foil). Results showed that false

identifications were most likely to be made to the familiar foil as opposed to a never-before-seen foil. Because the participants in Brown et al.'s study were exposed to the mugshots in a different context, it is possible that participants who falsely identified the bystander believed that the original target person and the mugshot photo were the same person. Therefore, participants who make a familiarity error following a mugshot search can be assumed to have made either a conscious inference or a source monitoring error. Unconscious transference is unlikely because it is doubtful that an eyewitness would forget being shown photographs by a police officer.

The current study will attempt to tease apart conscious inference and source monitoring by asking participants to make source judgments for each lineup member. Specifically, participants will be asked to rate whether each lineup member was familiar from the mock crime video, the mugbook, or for some other reason. If participants who make a familiarity error to a familiar foil (a foil that was viewed in but not chosen from the mugbook) are making a conscious inference, the rating of the familiar foil should be high for the video and the mugbook. However, if participants are making a source monitoring error, the rating of the familiar foil should be high for the video only. Participants also could make a source monitoring error by indicating that the perpetrator was present in the mugbook.

Commitment Errors

Witnesses who initially select someone from a mugbook are likely to choose that same person again in a subsequent lineup task. Gorenstein and Ellsworth (1980) first showed that participants who choose from an initial search through photographs were highly likely to choose that same person in a later identification task. Commitment has

been demonstrated following exposure to a single showup (Haw, Dickinson, & Meissner, 2007), a medium number of mugshots (e.g., 50; Goodsell, Neuschatz, & Gronlund, 2009), a large number of mugshots (e.g., 767; Dysart, Lindsay, Hammond, & Dupuis, 2001), and even objects present on a recognition test (Schooler, Foster, & Loftus, 1988).

Memon, Hope, Bartlett, and Bull (2002) showed participants a mock crime video and half subsequently viewed a 12-photo mugshot search. This mugshot search contained a photo deemed the critical foil, which subsequently appeared in the perpetrator-absent lineup two days later. Note that because the actual perpetrator is not in a perpetrator-absent lineup, the correct response is to reject the lineup. Results showed that those who chose from the mugshot search were more likely to make an error by choosing the critical foil from the subsequent perpetrator-absent lineup. Their critical foil is what we refer to as a familiar seen foil. This illustrates that participants do sometimes rely on familiarity when making their lineup decisions. This design, however, confounded commitment and familiarity because the only familiar face in the perpetrator-absent lineup belonged to the critical foil. Therefore, he could have been selected either because he was familiar or because the witness had committed to that choice. Indeed, 8 of the 13 participants who selected the critical foil from the mugshots chose that foil again in the lineup. Memon et al. argued that commitment did not play a major role in lineup decisions in their study even though the subset of participants that could make such an error did so at a high rate ($P = .615$).

Goodsell et al. (2009) designed two studies that unconfounded familiarity and commitment. Participants began by viewing a mock crime. Half the participants were randomly assigned to complete a perpetrator-absent 50-photograph mugshot search and

the other half were dismissed. Participants viewing the mugshots were instructed that the perpetrator they saw may or may not be present and to indicate if they saw him among the photos. All participants returned a week later and viewed a perpetrator-present lineup. The lineup was presented simultaneously, which meant that all six photographs were visible at the same time. Lineups were tailored for each participant. Witnesses who chose from the mugshot search saw a lineup that contained the perpetrator, their prior mugshot selection, a familiar seen foil (i.e., an unchosen face from the mugshot search), and three never-before-seen or new foils. Witnesses who did not choose from the mugshot search (mugshot non-choosers) saw the perpetrator, a familiar seen foil, and four new foils. Witnesses who never viewed the mugshots saw the same lineup as the mugshot non-choosers, which to them consisted of five new foils and the perpetrator.

Results showed that mugshot choosers showed a robust commitment effect: 65% chose the same individual from the lineup that they had chosen a week earlier despite the actual perpetrator being present in the lineup. Interestingly, 75% of the mugshot non-choosers tended to reject the lineup. Thus it seemed that witnesses committed to their choice or their selection style (i.e., to not choose). Familiarity effects were rare; only three witnesses chose someone from the lineup that they simply had viewed in the mugshot search. Goodsell et al.'s Experiment 1 illustrated the power of the commitment effect but did not directly test the Memon et al. (2002) hypothesis. In Experiment 2, mugshot choosers were shown a perpetrator-present lineup that did NOT include their prior mugshot choice. If participants in Goodsell et al.'s Experiment 1 made their lineup choice based on familiarity, they should have shifted to either the familiar seen foil or the perpetrator in the absence of that choice. However, this was not the case. The majority

(P = .6) rejected the lineup because their prior choice was not present; they stayed committed to their selection. Many fewer responded on the basis of familiarity (P = .16 to the familiar seen foil and P = .12 to the perpetrator).

There were some differences between these two studies. First, Memon et al. (2002) used only 12 mugshots and witnesses made an identification 48 hr later from a perpetrator absent lineup, whereas participants in Goodsell et al. (2009) viewed 50 mugshots and witnesses made an identification one week later from only perpetrator present lineups. Perhaps fewer photos and a shorter delay made the familiar seen foil more memorable in Memon et al. Thus, when mugshot choosers saw a lineup that did not include their prior choice, they assumed they were wrong and chose the familiar seen foil. The current study will use a 48 hr delay but will still utilize a 50-photo mugbook.

It also could be the fact that participants in Goodsell et al.'s Experiment 2 were reluctant to choose from the lineup not because they did not see their mugbook choice but because they became confused by the familiarity evoked by both the perpetrator and the familiar seen foil. The current study will address this key difference and will utilize both perpetrator present (like Goodsell et al.) and perpetrator absent lineups (like Memon et al.) and manipulate whether a mugshot choosers' prior choice is included in the lineup (like Goodsell et al. and the 13 participants in Memon et al. who happened to choose the familiar seen foil) or not included (like the majority of Memon et al.'s participants).

A second goal of the current study will be to investigate the boundary conditions of commitment and familiarity. Given the detrimental effects of possible transference of familiarity and commitment, can a mugshot search ever be effective in aiding police without harming subsequent lineup performance? Lindsay, Nosworthy, Martin, and

Martynuck (1994) demonstrated that mugshots could be a useful tool for a police investigation. They found that witnesses that searched though a large pool of mugshots (up to 727) that included the perpetrator, were able to select the perpetrator among a group of selected photos using a "might be" criterion. Lindsay et al. (1994) did not, however, use a perpetrator absent mugbook or require a formal lineup identification of these participants.

Thus, the current study will vary task goals to explore whether familiarity or commitment errors are due to how a participant approaches the mugbook task. Participants in the perpetrator search condition will be asked to search through the mugbook looking for the perpetrator (as in Goodsell et al., 2009). However, participants in the look alike condition will be asked to search though the mugbook and select any photos that resemble the perpetrator. Participants must choose at least one photo but no upper limit was given.

The lineups for the perpetrator search and look alike conditions will include either a participant's choice or not. Participants in the choice included condition will have their mugshot choice placed in the lineup (perpetrator search) or a randomly selected photo from the pool of photos the participant chose that resembled the perpetrator (look alike). Participants in the choice not included condition will not see any prior choices in the lineup. We predicted that participants in the perpetrator search condition would show poor performance on the lineup task due mainly to commitment errors. We also expected the rate of commitment to be higher in perpetrator absent lineups given that there would be fewer familiar options (i.e., the perpetrator is missing) to compete for lineup choices. For the look alike condition, participants in the choice included condition can make a

type of commitment error by selecting the foil (known as familiar selected) that was among the ones previously identified as looking similar to the perpetrator. We predict this will occur at a lower rate than in the perpetrator search condition given that their task is not to identify a single individual as the perpetrator. Selecting one foil in the perpetrator search condition should create a strong trace in memory whereas selecting several look alike foils should create several weaker (relative to a committed foil) traces. The reduced likelihood of a commitment error might protect the correct identification rate in the look alike condition.

Lineup errors due to mugshot exposure are clearly problematic for the criminal justice system as a witness may not be able to overcome a prior exposure to an innocent individual and correctly identify the perpetrator. Thus another goal of the current project is to investigate alternative methods that might protect the witness's memory from the deleterious effects described above. In addition to trying to limit commitment and familiarity errors through the look alike manipulation, we also sought to explore another technique that could protect against the deleterious effects of mugshot exposure and perhaps even facilitate performance.

Mugshot Learning Condition

Gronlund, Carlson, Dailey, and Goodsell (2009) compared sequential and simultaneous lineup formats to determine under what circumstances a sequential lineup resulted in superior performance. In a sequential lineup, lineup members are viewed one at a time (much like in a mugshot search), and a decision is required for one lineup member before the next is presented. Two types of lineups were created. The perpetrator was included in a perpetrator-present lineup; in the perpetrator-absent lineup, the

perpetrator was removed and replaced with an innocent suspect. Gronlund et al. found that a witness was better able to discriminate the guilty from the innocent suspect when the suspect (guilty or innocent) was placed late (5^{th} position vs. 2^{nd} position) in the sequential lineup. We proposed that witnesses were learning something as the lineup unfolded, perhaps constructing a better memory probe. For example, upon viewing the first lineup member, a witness might determine that the nose looks right but the eyes do not or that the shape of the face is wrong. This would allow a witness to proceed to the next photo with a better idea of what they were looking for.

The findings of Gronlund et al. (2009) suggest that there are circumstances in which viewing intervening faces between study (the crime video) and test (a suspect appearing in the lineup) can benefit performance. Goodsell, Gronlund, and Carlson (2010) explored this idea using Clark's (2003) WITNESS model (discussed in depth below) and instantiated the idea that a witness gained more diagnostic information as he or she progressed through the sequential lineup. The idea also has found empirical support. Goodsell, Buttaccio, and Gronlund (2010) had participants evaluate six faces of known innocent individuals prior to viewing a lineup. These faces either matched the perpetrator to a high degree (fair faces), moderate degree (medium faces), or very low degree (irrelevant faces). A control group evaluated scenes rather than faces. Simultaneous lineup decisions were more accurate after having viewed the fair or medium faces compared to the irrelevant faces or scenes. Although exposure to intervening faces through a mugshot search usually results in a decrement in lineup performance, the mugshot learning condition in the present study will seek evidence of

whether having a different task goal while viewing the same intervening faces can improve subsequent lineup identification.

In sum, this paper has two primary aims: (1) To conduct an experimental study involving mugshot search, including an evaluation of modifications that might enhance the validity of these procedures; and (2) to use the results of this study, as well as prior studies, to develop a formal explanation of eyewitness identification that incorporates the impact of mugshot search.

METHOD

Participants

A total of 614 participants were recruited from courses at the University of Oklahoma and The University of Alabama in Huntsville. Participants received either course credit or a $15 gift card in exchange for their participation. All participants were treated in accordance with APA ethical guidelines.

Design

This experiment conformed to a 3 (Instruction: perpetrator search vs. look-alike vs. mugshot learning) x 2 (perpetrator present vs. perpetrator absent) between-participants design with the addition of a no-mugshot control group (perpetrator present and perpetrator absent). Participants in the perpetrator search and look alike conditions were assigned to either a choice included or choice not included condition. This resulted in a total of 12 cells. Note that participants in the perpetrator search condition could elect not to choose from the mugbook; these participants could only be in the choice not included condition.

Materials

Video. All participants viewed the same mock crime video utilized in Goodsell et al. (2009). In this video, a 20-year old man with brown hair and no facial hair enters an office and begins a conversation with a secretary. After 10 s the man hands the secretary a piece of paper. She takes the paper and exits the room. Following this, the perpetrator reaches into her purse and steals her wallet. The perpetrator is in view for 25 s.

Mugbook. A 50-photograph mugbook was created using photographs that matched the description of the perpetrator (see Goodsell et al., 2009 for a detailed description of the photo selection process). Photographs were presented in PowerPoint in the perpetrator search and look alike conditions. For the mugshot learning condition, the photographs were presented via a zPro (Zoomerang.com, 2007) web survey. Each photo was an 800 x 600 pixel head and shoulder photograph. Only one photograph appeared per slide and each photo was numbered from 1 to 50. Participants viewing the photos in PowerPoint were allowed to move back and forth through the photos and could view some more than once; participants viewed each photo only once in the mugshot learning condition.

Lineups. Lineups were custom made for each participant. Before describing the various lineup constructions, an explanation of the various lineup members is required. The guilty suspect was a photo of the perpetrator, which appeared in all perpetrator present lineups. New foils were photos that participants had not seen before (i.e., not in the mugbook). Some photos of individuals from the mugbook also appeared in the lineup. For a choice included condition, this was either the photo selected by the participant in the perpetrator search condition (called the committed foil) or a randomly

chosen photo from the subset of photos chosen by a participant in the look alike task (called familiar selected). Finally, all lineups included an individual who was in the mugbook (called familiar seen). Lineup construction for each condition is summarized in Table 1.

Procedure

The experiment took place over two sessions separated by 48 hr. In the first session, participants began by reading the informed consent. Following consent, participants viewed the crime video. After the video, all participants worked on a Sudoku puzzle for 5 min. After 5 min participants in the no-mugshot control condition were dismissed and asked to return 48 hr later. Participants in the remaining conditions (i.e., the mugshot exposure conditions) received one of three different instructional manipulations. Those in the perpetrator search condition were asked to search for the perpetrator. They were told:

> You are an eyewitness to the identity of the robber from the video. The actual purpose of the study is to see if you can identify the robber from a series of mugshots. You will see photographs that, just like in real police cases, may or may not include the robber from the video you just saw. Your task is to identify the person that you viewed in the video. You are free to look at each picture for as long as you like, and you may look at them more than once. If you feel the robber is among the photographs, write down which number photo. If you believe that the robber is not present among the photographs write 'not here'.

Participants in the look-alike condition were asked to pick out individuals who resembled the perpetrator. They were told:

> You are an eyewitness to the identity of the robber from the video. In real criminal cases the police may show you photographs to help them search for the criminal. Your task is to look though a series of mugshots that may or may not contain the robber from the video and pick out any that look like the robber you saw in the video. This would help the police look for the robber because they

> would know more about what the robber looked like. You are free to look at each picture for as long as you like, and you may look at them more than once. Write down the number of any photograph that looks similar to the criminal you saw in the video. You can write down as many as you like.

Those in the mugshot learning condition were asked to rate each face for its similarity to the perpetrator. This was done to make sure the participants actually looked at each photo. Participants were directed to a web survey where they were presented the following on the screen:

> You are about to see 50 individuals that were NOT in the video you just saw. For each individual, please rate how similar this person looks to the robber from the video. Do this by assigning a similarity rating from 1, which is not at all similar, to 7, which is very similar. Reviewing each of these individual faces and making each of these decisions might help improve your memory for the robber. You will be asked questions about him later.

Below each photo was a 7-point similarity scale (1 = *not at all similar* to 7 = *very similar*). The participant was required to make a judgment for each photo by clicking one of the seven points using the mouse.

All participants returned after a 48 hr delay and viewed a lineup that was either perpetrator present or perpetrator absent, contained a prior choice or not (perpetrator search and look alike only), contained a familiar seen foil (mugshot conditions only), and new never-before-seen foils.

Confidence assessment. Following each subject's lineup identification, they were asked to indicate how confident they were in their decision on a 1 (*not at all confident*) to 7 (*very confident*) Likert scale.

Source judgments. After making a lineup decision and indicating their confidence, participants were asked to make three separate judgments (or two, if in the no-mugshot control) about each lineup member. Participants were instructed:

For each lineup member you will be asked how familiar that person is to you. You will rate each of the six persons on a 1 to 7 scale. You must decide if each lineup member seems familiar because he:

(1) was in the **video** and/or

(2) was among the **mugshots** you looked at in session 1 and/or

(3) seems familiar for **some other reason** (e.g., they look like someone you know, or you can't explain why they are familiar - they just are).

RESULTS

Goodsell et al., (2009) reported 73% choosing from the mugbook. The current experimental protocol, which was very similar, also resulted in a high choosing rate from the mugbook (85%). Because of the rarity of mugshot non-chooser data, we present that data in Appendix A and do not consider if further. Therefore, for all subsequent analyses, we excluded data from participants that did not choose from the mugbook in the perpetrator search condition.

The analyses are organized as followed: (1) decisions from perpetrator present lineups, (2) decisions from perpetrator absent lineups, (3) overall effects that jointly consider perpetrator present and absent lineups, (4) effects of mugshot exposure, (5) confidence and (6) source data.

Perpetrator present lineups

What affect did the four instruction conditions (control, perpetrator search, look alike, mugshot learning) have on participants' abilities to correctly identify the perpetrator from perpetrator present lineups (see Table 2)? A 4 (instruction conditions) x 2 (correct identification vs. other identification) hierarchical log-linear (HILOG) analysis was conducted; effect size measures are presented as Cramer's phi (ϕ_c). The HILOG revealed marginal differences in correct identifications, $\chi^2(2) = 7.532$, $p = .057$, $\phi_c = .160$.

Follow-up chi-square tests were performed and two significant effects emerged. A significantly greater number of participants in the no-mugshot control condition compared to the perpetrator search condition were able to correctly identify the perpetrator, $\chi^2(1) = 4.100$, $p < .05$, $\phi_c = .169$. Also, a significantly greater number of participants in the look alike condition compared to the perpetrator search condition were able to correctly identify the perpetrator, $\chi^2(1) = 6.787$, $p < .05$, $\phi_c = .196$. In other words, making a single selection from the mugbook in the perpetrator search harmed performance but making many selections in the look alike condition did not. The mugshot learning condition did not differ from any of the other three conditions.

Perpetrator absent lineups

The lineup rejection rate also yielded marginal differences among instruction conditions, $\chi^2(2) = 7.336$, $p = .062$, $\phi_c = .159$. The control condition had the lowest lineup rejection rate (greatest choosing). Follow-up chi square tests indicated that both the perpetrator search ($\chi^2(2) = 4.746$, $p < .05$, $\phi_c = .177$) and the mugshot learning ($\chi^2(2) = 6.301$, $p < .05$, $\phi_c = .243$) conditions resulted in more correct rejections than the control condition. Participants in the look alike condition tended to reject the lineup more often than the control condition, however this difference was not significantly different, $\chi^2(2) = 3.182$, $p = .074$, $\phi_c = .141$. This replicates prior work showing that mugshot exposure leads to more conservative lineup choosing (McAllister et al., in press). A detailed discussion of identifications from perpetrator absent lineups is included below under the discussion of the deleterious effects of mugshot exposure.

Overall performance

For all lineups, we were interested if any of the four instruction conditions affected participants' abilities to make a correct decision. A correct decision includes selecting the guilty suspect from perpetrator present lineups and rejecting perpetrator absent lineups. The HILOG revealed no significant effect of instruction, $\chi^2(2) = 3.865$, $p = ns$, $\phi_c = .081$. Although there were significantly more correct identifications in the control and look alike conditions compared to the perpetrator search condition, the greater choosing from perpetrator absent lineups led to the null result for overall performance. Given the ineffectiveness of the mugshot learning condition, we dropped it from subsequent analyses. Additional research will be necessary to understand why the current results failed to replicate Goodsell, Buttaccio, and Gronlund (2010); a topic we take up in the General Discussion. We turn next to the types of lineups errors that occurred following either the perpetrator search or look alike instruction.

Deleterious effects of mugshot exposure

Perpetrator search. Goodsell et al. (2009, Experiment 1) showed that mugbook choosers would select their prior choice in a perpetrator present lineup. As can be seen in Table 2, for the choice included condition, the committed foil error (labeled commit in the table) represented the majority of all lineup decisions compared to all other decisions combined, both in perpetrator present lineups ($P = .69$, $Z = 3.30$, $p < .05$) and even more so in perpetrator absent lineups ($P = .81$, $Z = 5.22$, $p < .05$).

Memon et al. (2002) showed that mugshot choosers shown a lineup that did not contain their choice would shift their choices to a familiar seen foil while Goodsell et al. (2009) found that participants tended to reject the lineup. In the choice not included

condition, the most frequent error in the perpetrator present lineups was a lineup rejection (P =.40). This error occurred more often than choosing either the perpetrator (P = .18, Z = 2.41, $p < .05$) or a new foil (P = .15, Z = 2.68, $p < .05$) but was not significantly different from choosing a familiar seen foil (P = .28, Z = 1.40, $p = ns$). In the perpetrator absent lineups, the majority of lineup errors were made to the familiar seen foil (P = .38), which occurred more often than selecting a new foil (P = .18, Z = 2.11, $p < .05$). A correct rejection (P = .44) occurred more frequently than selecting a new foil (Z = 2.73, $p < .05$) but less often than the selection of a familiar foil (Z = 0.64, $p = ns$). Thus there was support for both the Memon et al. (2002) and Goodsell et al. (2009) findings. Further consideration of this finding can be found in the Discussion section.

Look alike. One goal of the look alike condition was to avoid the negative consequences of commitment. As mentioned above, this procedure resulted in no decrement in the correct identification rate compared to the no-mugshot control condition. Apparently, these task instructions created a situation where witnesses were less likely to commit to a single choice, but there was an opportunity to make an error due to familiarity. As can be seen in Table 2, for the choice included perpetrator present condition, the familiar selected foil received the greatest number of identifications (P = .36). This occurred significantly more often than an incorrect rejection (P = .09, Z = 3.22, $p < .05$), a familiar seen foil (P = .13, Z = 2.64, $p < .05$), and a new foil selection (P = .15, Z = 2.36, $p < .05$). There were no differences between a familiar selected foil and the guilty perpetrator (P = 0.28, Z = .885, $p = ns$). In perpetrator absent lineups, the familiar selected foil received the greatest number of identifications (P = .30). This occurred at a similar rate to correctly rejecting the lineup (P = .20, Z = 1.12, $p = ns$), an

incorrect selection of a familiar seen foil ($P = .26$, $Z = 0.43$, $p = ns$), and a new foil ($P = .24$, $Z = .67$, $p = ns$). It seems that even in the look alike condition, some form of commitment can occur. The act of choosing these photos made it likely that one of these photos would be chosen again, but not as likely as if they committed to a single choice.

Confidence measure

Following a lineup decision, each participant was asked to rate their confidence in that decision on a seven-point Likert scale (1 = *not at all confident*, 7 = *very confident*). A 3 (instruction) x 2 (perpetrator presence) ANOVA was performed on the confidence ratings. Results of the ANOVA indicated a significant instruction by perpetrator presence interaction, $F(2, 456) = 6.042$, $p < .05$, $\eta_p^2 = .015$. Confidence for the no-mugshot control condition was similar between perpetrator present and absent lineups. Although there was a significant interaction for the perpetrator search and look alike conditions, it is problematic to interpret given that the data combine whether the choice was included (choice included was non-significant) as well as the type of choice made (i.e., committed foil, perpetrator, familiar seen, etc.). A 2 (instruction: perpetrator search vs. look alike) x 2 (choice) included ANOVA revealed no effects of the choice included variable, $F(1, 353) = 1.07$, $p = ns$, $\eta_p^2 = .003$.

Effects of commitment on confidence. In order to determine if including a committed foil in the lineup affected eyewitness confidence, a 3 (Instruction) x 2 (perpetrator presence) ANOVA was performed. For the perpetrator search condition, only those who made a commit-to-foil error were included in the analysis. For the look alike condition, only those who made a familiar selected error were included. Results of the ANOVA revealed no significant main effect of instruction, ($F(1, 200) = 1.215$, $p =$

ns, $\eta_p^2 = .012$), perpetrator presence (F (1, 200) = .725, $p = ns$, $\eta_p^2 = .004$), or the interaction between the two (F (2, 200) = .215, $p = ns$, $\eta_p^2 = .003$). Goodsell et al. (2009) also reported no differences in confidence for those making a commitment error.

Effects of familiarity errors on confidence. No significant difference emerged when comparing the confidence of those individuals who selected a familiar seen foil compared to others within their own condition, or to the no-mugshot control. Research on confidence and accuracy reveal that confidence is often not a good indicator of identification performance (Leippe & Eisenstadt, 2007). Studies that have found a confidence-accuracy relationship tend to find it with correct identifications (Brewer & Wells, 2006). Therefore, we conducted a 3 (instruction) x 2 (correct identification vs. other identification) ANOVA on the confidence measure for those who chose from the lineup. No significant effects emerged.

Source judgments

Of particular interest for the current research was how participants allocated their source judgments following making either a correct identification, commitment error, familiarity (seen and selected) error, new foil identification, or a lineup rejection, in the perpetrator search and look alike conditions. As described above, these responses may provide insight into the memory mechanisms behind these errors. For example, if a participant rated an incorrect selection of a foil they saw (or chose) in the mugbook as likely occurring in both the mugbook and the video, it would be consistent with a conscious inference; however, if a participant rated that incorrect selection as highly likely to have been present in the video but not the mugbook, it would be consistent with a source error. The average source ratings are listed in Table 3. The first column lists the

type of error the participant made. These are: a commitment error, identifying the familiar selected foil, the familiar seen foil, the perpetrator, or rejecting the lineup.

Commitment errors. In the perpetrator search choice included condition, 70% and 81% committed to their earlier mugshot choice from the perpetrator present and perpetrator absent conditions, respectively. In both cases this mugshot choice was rated as likely to have been in both the mugbook (perpetrator present $M = 6.16$ and perpetrator absent $M = 6.49$) and the video ($M = 4.88$ and $M = 6.16$). This is consistent with an error due to conscious inference. For these same participants, the perpetrator was rated as no different from the familiar seen foil, misattributing the perpetrator's familiarity more to the mugbook ($M = 3.00$) than the video ($M = 1.96$). It seems that this judgment is most likely a source error.

Familiar selected errors. Also of interest is how participants in the look alike condition evaluated lineup members compared to a familiar selected option. This situation is most similar to those making a commitment error from the perpetrator search condition. Like the perpetrator search commitment errors, the familiar selected foil was rated as highly likely to have been in both the mugbook (perpetrator present $M = 5.94$ and perpetrator absent $M = 6.00$) and the video ($M = 5.06$ and $M = 5.20$). Again, it is evident that participants remember their prior look alike selection from the mugbook and endorse that they saw him in the video too, suggesting that they are making a conscious inference error.

Familiar seen errors. In both the perpetrator present and perpetrator absent choice not included conditions, the familiar seen foil received a high rating for both the mugbook ($M = 5.82$ and $M = 5.41$), and the video ($M = 5.73$ and $M = 5.29$), indicating a

conscious inference that the familiar foil must have been in the video. The perpetrator was rated as somewhat likely to have appeared in the mugbook, misattributing his familiarity to the mugbook (M = 3.55) instead of the video (M = 1.91). Like those who committed in the perpetrator search condition, it seems that this judgment is most likely a source error.

There were a small number of participants who selected the familiar seen foil in the look alike conditions, so these results should be interpreted with caution (see Table 3 for cell sizes). For the choice included and not included conditions in the perpetrator present and perpetrator absent lineups, the familiar seen foil was rated as highly familiar from the mugbook (choice included: M = 4.50 and M = 5.61; choice not included: M = 4.00 and M = 4.31) and the video (choice included: M = 5.67 and M = 4.31; choice not included: M = 4.63 and M = 5.55). Participants in the choice included condition also recognized the familiar selected foil in both perpetrator present and absent lineups (M = 4.00 and M = 5.62). Like prior findings, the attributions for the perpetrator seem to be a misattribution to the mugbook (choice included: M = 4.67; choice not included M =3.88) instead of the video (choice included: M = 1.33; choice not included M = 2.38), indicating a source error.

Correct identifications. Interestingly, across all conditions, participants who identified the perpetrator tended to rate him as familiar from both the mugbook and the video (see Table 3). It seems that participants are making a source error by assuming they saw the perpetrator in the mugbook.

No identifications. In the perpetrator search choice included condition, only six participants rejected the lineup (2 in perpetrator present and 4 in perpetrator absent),

because most participants chose their prior mugbook selection. In the choice not included condition, participants from both the perpetrator present and perpetrator absent conditions recognized the familiar seen foil from the mugbook (M = 4.81 and M = 3.85) more so than from the video (M = 2.18 and M = 1.95). That means that these participants did not confuse the source of that foil. Participants in both choice included and not included conditions did, however, make a source error by confusing the familiarity evoked by the perpetrator by attributing him to the mugbook (M = 3.25 and M = 4.38).

In the look alike choice included condition, there were a small number of participants who rejected the lineup, but a fair number in the choice not included condition. As can be seen in Table 3, in perpetrator present and perpetrator absent lineups, familiar foils were correctly attributed to the mugbook and not the video. Again the few participants who rejected the lineup in the perpetrator present condition made a source error and misattributed the source of the perpetrator to the mugbook (choice included: M = 3.25; choice not included: M = 3.89) instead of the video (choice included: M = 2.25; choice not included: M = 2.22).

Overall we found two main findings from the source ratings. First, participants who chose a lineup member who they had previously seen or selected in the mugbook rated that choice as highly likely to have occurred in both the mugbook and the video. These errors are explained by conscious inference (Ross et al., 1990): participants remember both the video and mugbook contexts, but infer that the foil from the mugbook was in the video. Second, when evaluating the perpetrator in the lineup, most participants fell prey to a source error (Johnson et al., 1993) by attributing his familiarly

to the mugbook. This occurred even for participants who correctly selected him in the lineup as well.

DISCUSSION

Perpetrator Search Condition

The results of the experiment reveal the joint effects of commitment and familiarity in the perpetrator search conditions and look alike conditions. A review of these effects sets the stage for the computational modeling of these effects. In the perpetrator search condition, we found clear evidence for a commitment effect. The majority of participants who chose from the mugbook selected that same individual in a perpetrator present lineup (P = .695). An even higher proportion committed in the perpetrator absent lineups (P = .814, see Table 2). The perpetrator present condition replicates prior work on mugshot commitment (compare top rows of Table 4 illustrating that we replicated Goodsell et al., 2009, Exp. 1). One important goal of the modeling exercise will be explain how commitment effects arise.

How do witnesses respond if their choice is not present? Recall from the discussion above that Memon et al. (2002) concluded that mugbook choosers viewing a perpetrator absent lineup were likely to select a familiar seen foil while Goodsell et al. (2009, Exp. 2) used perpetrator present lineups and found that participants were likely to reject the lineup (see Table 4). Although these two results seem competing, we believe that both are correct and reveal differing strategies participants use to make these decisions. For example, some participants commit and between P = .40 (Memon et al.) and P = .60 (Goodsell et al.) of these participants stay committed to their choice and reject the lineup when they cannot find that choice. However, from P = .16 to P = .378

of the participants do not reject and instead select the familiar seen foil. The fact that some participants stay committed while others move to another familiar option might indicate the use of differing decision strategies by different individuals. It also might signal a shift from a reliance on recollection to a reliance on familiarity. We will explore these ideas below. However, to preview, the present study did not always provide detailed enough data to demarcate these strategies. Although the modeling exercise will reveal some of the underlying mechanisms, it will point to the experiments necessary for testing the more detailed hypotheses. The source data provides a start on the type of data we need.

It was clear from the source data that regardless of whether participants made a commitment error or not, participants tended to recognize their prior choice as being highly familiar from the mugbook, regardless of their lineup decision (see Table 3). This eliminates the possibility of unconscious transference, because they remember both the video and mugbook context. Participants who did make a commitment error consciously infer their choice was in the video. They also make a source monitoring error by indicating the perpetrator was in the mugbook. The obvious problem with an error like this is that a witness who has committed to an incorrect choice may have a difficult time providing useful information regarding the perpetrator. Indeed, Jennifer Thompson (the victim who misidentified Ronald Cotton) explained that when Bobby Poole (the real perpetrator) was implicated as the culprit she first denied it as a possibility and claimed that even after DNA proved Cotton's innocence, she still saw his face (and not Poole's) when she recalled the attack (Loeterman, 1997).

In the choice not included condition, some participants allocated their choices to other familiar foils (the familiar seen and the perpetrator) and their source data indicated that they thought their choice was in both the mugbook and the video. Thus, when making a decision, (i.e., where to set a criterion, or how to compare various lineup members) the inclusion of these foils would affect how they choose. This means that some participants may be relying on a strategy of familiarity and are simply picking the best matching mugbook or lineup member. The participants that rejected when their choice was not present indicated that the familiar foils were familiar from the mugbook only. This means other participants may be looking for their prior choice, and although they recognize that the familiar seen foil is indeed familiar, do not rely on familiarity alone to make their lineup decision.

Look Alike Condition

We found evidence that the look alike instruction did not harm a witness' ability to identify the perpetrator from a lineup (compared to the no-mugshot control condition). Is that because the look alike instructions mitigated the commitment effect? There was some evidence of this. Of the 12 participants who selected only one foil in the look alike task, only two subsequently chose that individual from the lineup. The decision strategy deployed by a participant may depend on the number of familiar choices in the lineup. In the choice included condition, a number of participants chose the familiar selected foil; these choosing rates were similar between perpetrator present (P = .362) and perpetrator absent lineups (P = .300, see Table 2). A more puzzling finding was the differing rates at which the familiar seen foil was endorsed between perpetrator present (P = .128) and perpetrator absent (P = .260). It seems that the subset of participants who would have

chosen the perpetrator (P = .276) allocate their choices to either the familiar seen foil or reject the lineup. In the choice not included perpetrator present condition, most of the participants that would have chosen the familiar selected foil (P = .362 in the choice included condition) decide to reject the lineup. Surprisingly, in the perpetrator absent condition, many of these choices are allocated to new foils. This finding, which will be difficult for the model to explain, will be discussed below.

THEORETICAL DEVELOPMENT

The remainder of this paper is devoted to applying a computational model to the data from the current and prior empirical studies. Clark's (2003) WITNESS model is the first, and to date only, formal, computational model of eyewitness identification. Computational models frequently are used in the field of cognitive psychology to explain various memory and decision-making phenomena. The use of computational models allows researchers to better specify their theories and has several advantages over verbal explanations of phenomena. These include allowing for a deeper understanding of existing data, making constructs and assumptions precise, as well as the generation of new and novel predictions (Bjork, 1973; Hintzman, 1991; Lewandowsky, 1993; Shiffrin & Nobel, 1997).

WITNESS assumes that when presented with the lineup, the only information in memory consists of a degraded representation of the perpetrator. No other traces from faces or events experienced before or after the crime are included. However, as we will demonstrate, because the perpetrator is the only trace in memory, WITNESS cannot account for phenomena where other traces influence performance. Mugshot exposure is one such phenomena. WITNESS will need to be modified to function more as a global-

matching model, thereby allowing an influence from other traces (see Clark & Gronlund, 1996, for a review). To accomplish this, we propose adding additional traces to the WITNESS framework to yield a new model, *WITNESS-ME* (ME for Mugshot Exposure). We begin with a description of the original WITNESS model and how it has been applied to eyewitness data.

WITNESS Model

In WITNESS, memory for a perpetrator is represented as a vector of features. These features are abstract and are not necessarily tied to specific physical features (e.g., eye color). Many memory models make similar assumptions (e.g. MINERVA 2; Hintzman, 1988). First, the model generates a 100-item vector (representing the perpetrator) with each feature taking a random value between -1 and 1. Next, this perpetrator is stored in memory. The quality of the encoding is tied to the parameter *c,* which governs how well a witness' memory for the perpetrator matches the actual perpetrator. The parameter *c* is a probability specifying whether an individual feature will be copied correctly into memory or replaced with a different random value (with probability 1-*c*).

The model creates a perpetrator present lineup by placing the guilty suspect (the perpetrator) into the lineup along with the foils. Foils are generated using the parameter *SFP* (Similarity of the Foils to the Perpetrator). As *SFP* (also a probability) approaches 1.0, the degree of match between the foils and the perpetrator increases. In a perpetrator absent lineup, the guilty suspect is replaced with a designated innocent suspect, generated using the parameter *SSP* (Similarity of the Innocent Suspect to the Perpetrator).

In addition to these parameters governing memory, WITNESS includes decision machinery to make a lineup identification. These parameters govern a witness' willingness to make a response and how match values are translated into a decision. In a sequential lineup, the model assumes that a witness computes the match between the current lineup member and memory (i.e., the dot product between the vector describing the current lineup member and the vector describing the perpetrator). If that match value exceeds the decision criterion ($crit_{SEQ}$), the witness chooses that lineup member; otherwise the witness rejects that lineup member and views the next.

The decision process is more complex for a simultaneous lineup. WITNESS assumes that human witnesses consider both an absolute and a relative contribution when making a lineup decision (see Wells, 1984 for a discussion). For the absolute contribution, it is hypothesized that a witness compares one lineup member to their memory of the perpetrator. The model computes the relative contribution as the difference in match values between the best matching lineup member (BEST) and the next-best matching lineup member (NEXT). These components are weighted by *wa* and *wr*, respectively (note *wa* + *wr* =1). The model chooses the BEST when [*wa**BEST + *wr**(BEST-NEXT)] exceeds $crit_{SIM}$. In a description-matched lineup (Wells, Rydell, & Seelau, 1993) – one in which lineup members are chosen based on their match to a witness's description of the perpetrator – these weights have little effect (see Goodsell, Gronlund, & Carlson, 2010). All lineups dealt with in this paper are description-matched; therefore, these two weights were set to .5.

A theoretical explanation of lineup identification is accomplished by adjusting WITNESS' parameters to approximate the data. To see how this is done, take two

hypothetical experiments: Study A employs a mock crime video with a good view of the perpetrator, the designated innocent suspect matches the guilty perpetrator poorly, and the lineup foils are poor. Participants were instructed to choose the suspect from the lineup. Study B employs a mock crime video that affords a poor view of the perpetrator, the designated innocent suspect is highly similar to the guilty perpetrator, and the lineup foils are similar to him indicating that the lineup was fair. Participants were instructed that the lineup may or may not contain the suspect. In order to fit the model to these two experiments we would use a higher value of *c* in Study A than B (e.g., .3 vs. .15). The *SSP* parameter would be low in Study A and high in Study B (e.g., .3 vs. .8) and the *SFP* parameters would be low in Study A and higher in Study B (.25 vs. .5). The decision criterion would be adjusted to reflect the respective choosing rates (lower in Study A than Study B).

Previous research has shown that WITNESS can account for differences in suspect-matched and description-matched designs (Clark, 2003) as well as studies comparing simultaneous and sequential lineup procedures (Goodsell, Gronlund, & Carlson, 2010). However, prior applications of the model have operated with only one representation in memory—the perpetrator. We believe that one consequence of conducting a mugbook search is that we need to consider a model that has more than just the perpetrator in memory. The theoretical exploration that follows is organized as followed: First, evidence will be presented showing that WITNESS lacks sufficient machinery to account for the mugshot exposure effect. Next, an extension of WITNESS will be presented as a solution and applied to the data from the current study as well as to

the Memon et al. (2002) and Goodsell et al. (2009) data. Following this, we turn our modeling efforts to the look alike condition.

Mugshot Exposure with WITNESS

Goodsell et al. (2009) found that mugshot choosers selected their prior mugshot choice at a high rate (65%) in a lineup that contained the actual perpetrator, a familiar seen foil, and three new foils. Modeling data like these presents a challenge to the WITNESS model. Two additional types of foils need to be considered in the perpetrator search condition. One results when the witness makes a choice from the mugbook. We refer to this as the committed foil and the similarity of the committed foil to the perpetrator is governed by *SCF* (denoting the Similarity of the Committed Foil to the perpetrator). The committed foil must resemble the perpetrator to a high degree given that a witness would select this individual from the mugbook as the perpetrator. The other type of foil is termed the familiar seen foil. This is an individual that was in the mugbook but was not chosen. Therefore, this individual should bear little resemblance to the perpetrator. Moreover, the selection of this individual from the lineup signals a reliance on familiarity from prior exposure more so than similarity to the perpetrator.

Model selection was accomplished by finding a parameter set that maximized r^2 as an indication of trend relative magnitude and minimized root mean squared deviation (*RMSD*), which is the square root of the mean of the squared deviation between the model and the data (see Schunn & Wallach, 2005). Parameter adjustments were done manually rather than by an automated algorithm. Consequently, a model that adequately fit the data by our criterion was not necessarily the best-fitting model (although it likely was close to the best-fitting parameter set).

The original WITNESS model did a poor job of approximating the data (*RMSD* = .233; r^2 = .078). Specifically, the model selects the committed foil too infrequently and the guilty suspect too frequently. The Goodsell et al. (2009, Exp. 1) data show that the committed foil was chosen significantly more than the perpetrator (*P* = .649 vs. *P* = .095). Why does the WITNESS model fail to capture this? Because WITNESS maintains only a degraded version of the perpetrator in memory, and because all lineup members are degraded versions of the guilty perpetrator, no other lineup member could be a better match than the perpetrator. The model chose the perpetrator too often (*P* = .456) and the committed foil not enough (*P* = .273).

A second possibility to bring WITNESS in line with these data involves changing what is stored in memory. Perhaps there is only one thing in memory (of relevance to the task), but when a witness makes a mugshot choice, that choice replaces the perpetrator trace in memory. Schooler, Foster, and Loftus (1988) suggested that committing to an incorrect alternative impairs memory for the original event, rendering it inaccessible. Implementing this idea in WITNESS would involve replacing the original memory vector of the perpetrator with that of the committed foil.

This idea was implemented by having the model replace the perpetrator trace with the mugbook choice for those participants that chose from the mugbook. We applied this model to the perpetrator search condition for both the choice included and choice not included conditions from the current study. The encoding of the mugshot choice was governed by a new parameter c_{mug}. This variation of the WITNESS model also failed to fit the data (choice included fit: *RMSD* = .145, r^2 = .703). The model could accurately account for occurrences where a witness committed to a previously chosen foil, but the

familiar seen foil was not chosen at a sufficiently high rate. This was especially true when the prior choice was not included (choice not included fit: *RMSD* = .281, r^2 = .119).

It appears that multiple-exposure extensions to WITNESS are required given the difficulty of the fitting either single trace model to the data. We also need to consider evidence from Zaragoza and colleagues (McCloskey & Zaragoza, 1985; Zaragoza, McCloskey, & Jamis, 1987) that participants have access to both suggested information and their original memories following misleading post-event information. The Goodsell et al. (2009) data also supported this interpretation: 9.5% of their participants who choose from the mugbook were able to accurately select the perpetrator and reject their prior mugshot choice. This might seem like a small percentage but of the 26 participants that did not stay committed to their mugshot choice, 7 chose the perpetrator. Additionally, many participants that did not choose the perpetrator still rated him as familiar; the source data indicated that he was familiar from the mugbook rather than the video (see Table 3). Thus it seems reasonable to assume that memory for the perpetrator still existed following mugshot exposure, but committing to someone from the mugbook added a strong competitor to memory. Moreover, given that the familiar seen foil was often identified in the lineup, we assumed that a number of the mugbook foils entered memory.

The incorporation of multiple traces into WITNESS makes this extension (WITNESS with Mugshot Exposure or WITNESS-ME) a global matching model (see Clark & Gronlund, 1996). We begin with a description of WITNESS-ME and how it can be applied to the perpetrator search data and studies that employ this type of design. We follow this with a discussion of how the model needs to be modified to address the look alike data.

The WITNESS-ME Model

Representational assumptions. Like WITNESS, WITNESS-ME assumes that memory for a perpetrator can be represented as a vector of features. Subsequent events (i.e., mugshot faces) also are represented as separate traces. WITNESS-ME operates as follows: first, a *j*-element vector (for all simulations presented here, $j = 100$) representing the perpetrator is generated (**Perp)**, with each feature containing a randomly generated value between -1 and 1. A degraded version of **Perp** is stored in memory (**Mem)** and is tied to the encoding parameter, $perp_c$. Encoding involves copying each element into **Mem** with a probability, $perp_c$. This parameter replaces *c* in WITNESS.

In order to evaluate photos in a mugshot search, as well as photos in a lineup, the model needs to specify these. For a mugbook of size *N*, foils are generated with the parameter *SMP* (denoting the Similarity between the Mugshots and the Perpetrator), which specifies the probability that each feature will match that of the **Perp**. As with encoding, if a feature is not stored (with probability 1-*SMP*), it is replaced with a value of 0. As *SMP* increases from 0, the degree of match between the mugbook foils and the perpetrator increases. For a given value of *SMP*, all mugbook foils would match the perpetrator, on average, equally well. However, there would be a lot more variability among mugphotos in reality. A more plausible implementation of a mugbook would have *SMP* be the mean of a normal distribution with variance σ^2. However, this additional complexity was not employed here.

Lineup foils are generated in the same way as in WITNESS. The parameter *SFP* (denotes the Similarity of the lineup Foils to the Perpetrator) varies the quality of the

lineup foils[1]. In designs that include a designated innocent suspect, the parameter *SSP* (denotes the Similarity of the innocent Suspect) adjusts for the similarity of the innocent suspect to the perpetrator. However, the current study did not have a designated innocent suspect.

Now that we have specified the stimuli necessary for a mugshot study, we turn our attention to a description of how WITNESS-ME compares foils to memory, how additional items are added to memory, and how it makes an identification decision.

Matching function. The match value for a given lineup member ***F*** to memory is computed by,

$$\textbf{Match} = \sum_{i=1}^{M} [\sum_{j=1}^{N} (\boldsymbol{F}_j \boldsymbol{Mem}_{i,j}) / N],$$

where $\boldsymbol{F}_j$ is the value of feature *j* in the lineup member, $\textbf{Mem}_{i,j}$ is the value of feature *j* in memory trace *i*. The products are summed across the *N* elements in a vector and divided by *N*. Then these activations are summed across the *M* traces in memory to yield **Match**.

Comparing foils and adding items to memory. After generating the perpetrator (**Perp)**, encoding it into memory (**Mem**), and generating a mugbook, (using *SMP*), the model must evaluate the mugbook and make a(n) decision(s). Recall that participants searched through a mugbook to find the perpetrator (perpetrator search) or to chose a subset of mugshots they believed looked similar to the perpetrator (look alike). We begin with the perpetrator search condition. In this condition, some participants chose and some did not. WITNESS-ME simulates the mugbook search by first computing the match value (**Match**) between each mugbook member and **Mem** (which at this point

[1] Note that in suspect-matched foil designs a different set of foils would be generated for perpetrator-absent lineups.

contains only the degraded version of **Perp**). The model evaluates **Match** for all 50 mugbook foils, identifies the highest match value, and compares that value to $crit_{mug}$. If **Match** is above $crit_{mug}$, then that simulated subject becomes a mugshot chooser and WITNESS-ME places that mugbook foil into memory with the encoding parameter com_c (encoding of the committed foil). WITNESS-ME also places that foil into the lineup for the choice included conditions. If the best match is less than $crit_{mug}$, then the simulated subject becomes a mugshot non-chooser and nothing is added to memory or to the lineup.

Based on evidence from studies of suggestion (Zaragoza et al., 1987) and transference effects (Phillips et al., 1997), as well as the finding that the familiar seen foil was often identified in the lineup (see Table 2), WITNESS-ME assumes that some subset of the mugbook foils enter memory in the process of evaluating them. We assumed this occurred in both the perpetrator search and the look alike conditions. We assumed that nine of these mugbook foils enter memory. Although this assumption is arbitrary, we found that varying the number of foils from 5 to 20 did not affect our ability to achieve similar model fits by adjusting other parameter values. These mugbook foils are encoded into memory with a probability mug_c. In order to place a familiar seen foil into the lineup, WITNESS-ME selects a mugbook foil (that was not chosen, but was placed in memory) at random. We chose to use the random selection method under the assumption that the familiar seen foil was not a foil that was chosen (as the perpetrator) and therefore, on average was no better than any other mugbook foil.

Lineup construction. The final phase of an eyewitness task following a mugshot search is the lineup identification. WITNESS-ME generates a perpetrator present lineup by placing **Perp** among other foils. In a perpetrator absent lineup, **Perp** is replaced with

a new foil. The remaining lineup foils depends on the particulars of the experiment but can be any combination of the committed foil (chosen from the mugbook), the familiar seen foil (appears in mugbook and lineup), the familiar selected foil (selected as a look alike foil – discussed below), or new (never-before seen) foils.

In WITNESS, a perfect replica of the perpetrator is placed in the lineup. However, in applying WITNESS-ME to the perpetrator search data, we found that this assumption did not work. Fitting the data with the perfect replica of the perpetrator resulted in more than twice as many identifications of the guilty suspect. Rather, we needed to assume that the guilty suspect placed in the lineup was not a perfect replica. We added the parameter *DGS* to reflect the degree to which the guilty suspect matched the perpetrator. *DGS*, like the other similarity parameters, is a probability that governs whether each feature of **Perp** will be properly represented in the lineup; features that are not properly represented are replaced with a random value between -1 and 1. Thus as *DGS* approaches 1.0, the guilty suspect more closely resembles how he appeared at the time of the crime. We will discuss the implications of this modification below.

Lineup decisions. For each lineup member, WITNESS-ME computes **Match**. In a simultaneous lineup, the model identifies the member yielding the highest match value (BEST) and the second highest match value (NEXT). As with WITNESS (Clark, 2003), the model chooses from a lineup when a weighted combination of the absolute and relative contributions exceed a decision criterion [(*wa**BEST + *wr**NEXT) > *crit*]. As

mentioned above, these weights have little impact on performance in description-matched designs and are held at .5[2]. The current study utilized only simultaneous lineups.

The decision criterion for the no mugshot control group was denoted *crit*. However, the decision criterion needed to take different values for the mugshot groups. If a common criterion value was used for the mugshot choosers and non-choosers, we found that the model performed poorly (e.g., the *RMSD* value was twice as large for the perpetrator search choice not included condition) compared to allowing different values for mugshot choosers and mugshot non-choosers. Goodsell et al. (2009) found that these two groups choose from lineups at different rates. Therefore, the decision criterion needed to take one of three different values: $crit_{mc}$ (denoting the decision criterion for Mugshot Choosers), $crit_{mnc}$ (denoting the decision criterion for Mugshot Non-Choosers), and *crit* (denoting the Criterion for the no-mugshot control).

Application of WITNESS-ME to the Perpetrator Search Data

To fit WITNESS-ME to the data, we need to consider the design of the study. This includes the size of the mugbook and the composition of the lineup. As mentioned, the mugbook utilized in the empirical portion of this study consisted of 50 photos. All lineups were 6-person, were either perpetrator present or perpetrator absent, and did or did not include the mugshot chooser's choice in the lineup. The lineup included a familiar seen foil in the mugshot conditions: the model randomly chose a foil that was not chosen from the mugbook search. One thousand simulations were conducted for each fit of WITNESS-ME to the data.

[2] To verify that this also was the case with WITNESS-ME, we fit the model to the perpetrator search data using a completely absolute rule (*wa* =1) and using a completely relative rule (*wr* = 1), and achieved similar fits to the data by adjusting only the decision criterion (following Goodsell et al., 2010).

We begin by applying WITNESS-ME to the perpetrator search choice included data from the current study as well as Goodsell et al. (2009, Exp. 1) and the perpetrator search choice not included data from the current study as well as Goodsell et al (2009, Exp. 2). The data include: the choosing rate from the mugbook, correct identifications, commit-to-foil identifications (choice included conditions), familiar seen identifications, new foil identifications, and lineup rejections. Overall, the model performed quite well. We describe the parameter values required to fit the data followed by a discussion of the fit.

The parameter values for the fit to the culprit search data can be found in Table 6 (parameter definitions are in Table 5). We held all the encoding parameters (mem_c, com_c, and mug_c) constant for the choice included and not included conditions because participants could not know which condition they were in. The value of mem_c could have varied between the current study and Goodsell et al. (2009), but given that we used the same crime video and similar materials, it is not surprising that the same value of mem_c worked for both.

According to WITNESS-ME, what factors are responsible for the commitment effect? A large value of com_c was required; making a mugbook choice created a very strong trace in memory. The value of mug_c also was large to get the model to choose the familiar seen foil at a high enough rate. Notice that the values of com_c and mug_c were smaller for the Goodsell et al. data; this makes sense given that these participants had a longer delay between viewing the mugbook and making a lineup decision. The relative ratio of com_c to mug_c influences the likelihood of making a familiarity error rather than a commitment error and could explain the difference between the Memon et al. and

Goodsell et al. data. Given that our familiar seen foil was one of 50 and Memon et al.'s was one of 12, it seems plausible that this ratio would be smaller for the Memon et al. data.

The value of *DGS* required to fit these data was .7, indicating that accounting for the commitment effect required the model to lessen the impact of the perpetrator. This was not required in fitting the look alike condition (discussed below) indicating that commitment affects memory for the perpetrator differently than simply being exposed to mugbook foils. Perhaps adding the committed foil to memory as a strong competitor for the perpetrator functions like the differentiation process proposed by Ratcliff, Clark, and Shiffrin (1990; see also Criss, 2006). That is, the accurate encoding of the committed foil makes other foils seem less related by comparison. In fact, perhaps participants do not "find" the perpetrator in the lineup because the committed foil becomes the new standard for comparison, and seldom is anything stronger in memory than the committed foil.

The decision criterion values were set to yield the proper choosing rates from both the mugbook and the lineup. Values of $crit_{mug}$ were held constant between choice included and not included conditions.

Model fit to choice included condition. Table 7 shows the data and the best fitting model results to the choice included conditions for both the current study and the Goodsell et al. (2009, Exp. 1). As can be seen in the top half of Table 7, the fit of the model to the data from current study was very good (*RMSD* = .042, r^2 = .98). Note that the mugbook non-chooser data is included even though these cells had a low sample size. The model also captures these data. Although the quantitative model fit is very good, there is a miss in the qualitative fit. The model selects the committed foil at a similar rate

between perpetrator present and perpetrator absent whereas the data showed that the committed foil was chosen more in the perpetrator absent lineup. One possible explanation is that the number of plausible options in the lineup may affect a participant's willingness to choose. In the perpetrator present condition there are three lineup members that should appear familiar, the perpetrator, a familiar seen foil, and a committed foil. In the perpetrator absent lineup there are only two (no perpetrator). Participants were less willing to choose in the perpetrator present condition, perhaps because having three plausible options made some participants unwilling to discriminate among them. By separately adjusting $crit_{mc}$ to fit the No ID rate of the perpetrator present and perpetrator absent lineups, the committed foil rates did differ (P = .676 and P =.777, respectively). Further consideration of the adjustments participants might make based on the alternatives they are considering can be found in the General Discussion.

The bottom half of Table 7 illustrates that the fit of WITNESS-ME to the Goodsell et al. (2009) data also was good ($RMSD$ = .057, r^2 = .967). Even though that study did not include a perpetrator absent condition, the model predictions (based on the parameters that fit the perpetrator present condition) can be seen in the columns to the right of the data. Although the overall fit is good, the model does not choose the perpetrator often enough. One solution to this misprediction could be if the data include some individuals with a very good memory of the perpetrator. These participants would not make a mugbook selection from the perpetrator absent mugbook but could still select the perpetrator from the lineup. However, the model is forced to fit the average participant, who had a very high criterion because most participants rejected the lineup. This would mask this subgroup of individuals with a good memory. This was not a

problem for the data from the current study because the choosing rate was much higher. Why was the choosing rate so different between these very similar studies? The primary difference was the effect the retention interval had on the choosing rate of the familiar seen foil. After a 48 hr delay, the familiar seen was the most frequent choice, but the familiar seen foil was never chosen after a one week delay. After a week the familiar seen foil is no longer familiar enough and for that reason the criterion is raised. This made it difficult for the model to do much of anything besides reject the lineup.

When we consider what could be happening in this situation we think the problem could be that there are three subgroups of witnesses that we are trying to fit with a model that assumes that all participants are behaving similarly. One subgroup might be mugbook non-choosers that continue to reject to remain consistent. A second subgroup may have very poor memory for the perpetrator and subsequently cannot find him in the mugbook or the lineup. A third subgroup actually may have a very good memory for the perpetrator. In support of this conjecture, to get the model to choose the perpetrator at the appropriate rate, encoding needed to be almost three times as large. This is consistent with a subgroup of participants with a very good memory for the perpetrator who would not make a mugbook selection because they did not find him in the mugbook, but due to their good encoding of the perpetrator, can still select him from the lineup. In sum, in spite of the good overall fit to the data, the misprediction hints at a greater underlying complexity regarding how participants deploy their memory and decision processes. Disentangling these three subgroups will require richer data that includes an indicator (via either manipulation or measurement) of initial encoding quality and willingness to choose.

Perpetrator search choice not included. The top half of Table 8 gives the fit to the data from the current study (*RMSD* = .037, r^2 = .975); the bottom half of Table 8 shows the fit to the Goodsell et al. (2009, Exp. 2) data (*RMSD* = .025, r^2 = .993). Both were very good. Although the Goodsell et al. experiment included only a mugshot chooser perpetrator present condition, the model predictions for the other three conditions can be found in the columns to the right of the data. Recall that the only parameters that were free to vary, relative to the choice included conditions, were $crit_{mc}$ and $crit_{mnc,}$ as participants wouldn't know which condition they were in at the time of encoding. Even with the strong trace of the committed foil in memory, the model captures the pattern of data from these two studies using a common set of parameter values, with slightly varying choosing rates.

Overall, the WITNESS-ME model captures the perpetrator search data very well. By including a strong trace in memory for the committed foil, weaker traces for familiar seen foils, and allowing mugshot choosers and non-choosers to differ in their decision criteria, the model accounted for the commitment effect and instances where participants reject the lineup because they cannot commit to their prior choice. The one misprediction involved the mugshot non-choosers in the Goodsell et al. (2009) data. Why were the non-chooser data from the current study not mispredicted? First, we should caution that the non-chooser data from the current study was based on small sample sizes. Second, perhaps those with poor memories may rely on familiarity and choose the familiar seen at high rates after a 48 hr delay but after one week that familiarity is gone and participants instead reject the lineup. Those with good memories can still pick out the perpetrator in

both cases, but the model cannot for the Goodsell et al. data because of the high criterion needed to fit the average.

Application of WITNESS-ME to the Look Alike Data

WITNESS-ME needs a few changes for the look alike data. Recall that we randomly chose a foil from the pool of mugshots selected by the participant and placed that choice in the lineup. To achieve this, the model computed the match values for all the mugshots and then randomly chose a foil from among the top six best matching mugshots. We chose this method because look alike participants chose six look alike foils on average. The selected foil was encoded in memory according to com_c, which should take a smaller value here than in the perpetrator search condition. The $crit_{mnc}$ parameter was not needed because everyone had to choose in the look alike task.

First we show that the look alike condition differs from the perpetrator search condition by illustrating how the model performed using the same parameter values (except $crit_{mc}$, which was adjusted to match the lineup choosing rate). For the choice included condition, the model over predicted the rate at which the familiar selected was picked in both the perpetrator present (P = .715 vs. .362) and the perpetrator absent (P = .737 vs. .300) lineup (overall fit: $RMSD$ = .221, r^2 = .513). The first modification we tried was to assume that making a look alike selection results in a weaker memory than making a mugbook selection in the perpetrator search task. This frees the com_c and mug_c parameters ($mug_c < com_c$). Unfortunately, this also proved inadequate ($RMSD$ = .078, r^2 = .373). One problem was that WITNESS-ME was under predicting the correct identification rate (model P = .118, data P = .277). Given the equivalent correct identification rate between the no-mugshot control condition and the look alike condition,

we reset the *DGS* parameter to 1.0, as in the control condition[3]. This helped (model P = .173) but still did not provide a good overall fit (*RMSD* =.068, r^2= .520). Although the model was mispredicting the lineup choosing rate in the perpetrator present case, simply adjusting the decision criterion to fit only these data was not sufficient to bring the correct identification rate in line with the data. Last, we considered that the look alike task may have caused our participants to engage in what we had hoped the mugshot learning task would have achieved. Perhaps selecting a subset of foils that looked similar to the culprit helped some participants develop a better probe of memory (Goodsell, Buttaccio, & Gronlund, 2010). To see if this idea had merit, we adjusted the value of mem_c to .20.

Adjusting mem_c was sufficient to bring the correct identification rate in line with the data; however, we found the same problem we discovered earlier with the differing choosing rates between perpetrator present and perpetrator absent lineups. Therefore, we allowed different criterion values; the top half of Table 9 presents the fit to the choice included data and the bottom half shows the choice not included for the model. The fit to the data was good except for the perpetrator absent choice included data. Looking at these data, we would expect that participants that still wish to choose would allocate their choices to the next most familiar foil, which should be the familiar selected foil. The model predicts this to be the case. However, the data illustrate that participants opt to choose the familiar seen foil much more. Why would they do this? Perhaps knowledge of the participants' opinion of the familiar selected foil would help answer this question. In the data, the familiar selected was a random choice of a pool of choices that varied

[3] Fit to the control condition: *RMSD* = .023, r^2 = .996. Parameter values: mem_c = .13, *DGS* =1.0, *SFP* = .53, *crit* =.021.

from one to twenty in our study, but the model only picks from among the 6 best. Therefore, the familiar selected foil that we randomly chose to put in the lineup was worse on average than what was chosen by the model. For this reason, the model selected the familiar selected more often. This modification helped, but the familiar seen still was chosen at a higher rate than the model expected. Future research will have to address why this occurs.

GENERAL DISCUSSION

Both an empirical and theoretical exploration of the mugshot exposure effect was undertaken. We conducted a large study exploring the effects of task instruction on subsequent lineup decisions. Additionally, we proposed an extension of Clark's (2003) WITNESS model, WITNESS-ME (ME for mugshot exposure) to aid our understanding of these effects. From our empirical work, we investigated how task instructions affected subsequent lineup decision making. Using an instruction we called perpetrator search, we replicated the mugshot commitment effect (Goodsell et al., 2009) – participants who view a mugbook with the goal of finding the perpetrator and subsequently choose, are likely to select that same individual (given the option) in a lineup. This occurred at a very high rate even when the actual perpetrator was present. Evidence from participants' source ratings indicated that those making the commitment error consciously infer that their mugbook choice was present in the video. When judging the perpetrator, participants misattributed the source of the familiarity evoked by seeing the perpetrator and judged him to be familiar from the mugbook and not the video.

Evidence from our modeling exploration highlighted two components to the commitment effect. First, selecting from a mugbook creates a strong trace in memory

that competes with other traces. For the current study, the encoding of the committed foil (com_c) was more than four times stronger than the encoding of the perpetrator (mem_c). Second, committing to a mugbook foil decreases the subjective strength of the perpetrator in memory as modeled using the *DGS* parameter. We suggested that the accurate encoding of the committed foil makes other foils seem like poorer matches by comparison.

WITNESS-ME provided a good fit to perpetrator search data from the current study and the data from Goodsell et al. (2009). However, because the model chose the committed foil at about the same rate between perpetrator present and perpetrator absent lineups in the choice included condition, we proposed that the number of plausible (i.e., familiar) choices in the lineup influences criterion placement. Thus in the perpetrator present lineup, where the perpetrator, committed foil, and familiar seen foil, all match memory fairly well, we needed to adjust $crit_{mc}$ to be higher than in the perpetrator absent condition (where there are only two familiar options). Benjamin and Bawa (2004) found that participants tend to become more conservative on recognition tasks when the number of plausible alternatives increased. Likewise, we found that a greater number of plausible lineup options caused participants to be less willing to make a commitment error.

When mugbook choosers viewed a lineup that did not contain their prior choice, some participants will allocate their choice to a familiar seen foil (Memon et al., 2002) while others opt to reject the lineup (Goodsell et al., 2009). One difference revealed by our modeling exercise was that the value of mug_c needed to be lower for the Goodsell et al. data. After the one week delay, memory for familiar seen foils apparently were so weak that that foil was no longer a viable option in the lineup. Indeed, if we took the

parameter values used to fit the perpetrator search choice included data from the current study and lowered mug_c from .45 to .15, the model predictions matched the Goodsell et al. (Exp. 2). Another possibility is that the longer delay makes witnesses more conservative in their lineup choosing. By increasing $crit_{mc}$ from .134 to .16, the model rejects the lineup at the same rate as in the Goodsell et al. study (P = .6) and the familiar foil identification rate drops from P = .27 to P = .20.

Our look alike condition demonstrated no loss in the correct identification rate compared to the no-mugshot control condition. Although this instruction protected the correct identification rate, a look alike foil who happened to become a suspect likely would be identified in a lineup: The choice included condition resulted in a fairly high rate of choices of the familiar selected foil (P = .362 in perpetrator present and P = .300 in perpetrator absent). It should be noted that there does seem to be some potential for this method. Lindsey et al. (1994) found that participants were able to include the actual perpetrator using a procedure similar to our look alike condition. We did not include the perpetrator, as we were interested in the mechanisms behind lineup errors. However, had we not set up our lineups in a manner that was quite difficult for our participants, we may have found even greater support for the use of this method. That is, it seems unlikely that the police would construct a lineup that included so many previously seen individuals. The condition with the least amount of familiar foils (perpetrator absent choice not included) actually had the highest correct identification rate. Future research should identify if this look alike procedure would be effective for witnesses viewing a lineup that contained only the suspect and new foils.

Modeling the look alike condition proved challenging. Clearly this task involved more than evaluating the best matching lineup member to criterion. One weakness of the current design is that we had no way of knowing how they evaluated each look alike photo, or to what degree any one selection was better than another. Given that participants were told that the perpetrator may or may not be present, it seems plausible that some of our participants chose believing that they had found the actual perpetrator (committed). Requiring a confidence estimate for each choice, or simply asking them if they believe the perpetrator was present among their choices may identity a subset of participants who are approaching the lineup task differently than those who believe they picked out innocent people who resembled the perpetrator. The fact that we constructed lineups by randomly choosing a look alike selection means we could have sub-divided our participants by whether they believed they had or had not chosen the perpetrator and by those who did or did not see that best choice. Although we probably could create modifications to WITNESS-ME that fit the pattern of data, it seems premature to do so given that we need a better understanding of the processes at hand. This requires collecting more data that answers questions like the ones raised above.

Future research is planned to investigate if we can identify individual differences as an indicator of one strategy (lineup choosing) over another (lineup rejection). One way to assess this would be to garner a confidence assessment following a selection from the mugbook. Those who are highly confident in their choice are the individuals probably are most likely to stay committed. However, those that are less highly confident might move to another familiar option in the lineup if their choice is not present or if they fail to recognize that it is. We need to ask participants how confident they are that the person

they selected from the lineup is the same person they picked from the mugbook. That would tell us if some participants are making a commitment choice even if they make a different selection. Additionally, it would be beneficial to ask participants how they made their decisions. It was evident from the source data that most participants remembered that their prior mugbook choice did appear in the mugbook. Do some of these witnesses view the reoccurrence of their prior choice as a confirmation of their original choice? Do they choose to remain consistent, or does choosing from a mugbook create a new memory trace that is so much stronger than that of the perpetrator that the only real viable choice is the committed foil? Indeed the low correct identification rate in the current study would indicate that memory for the perpetrator was generally weak. Perhaps commitment effects are strongest in these situations. Using a video that allowed for a better encoding of the perpetrator would better test these ideas.

To better test the look alike condition we need to know if our participants believe any of their choices are the perpetrator. Participants who believed they had found the perpetrator may have adopted a different approach to making a lineup decision (like those of the perpetrator search condition) compared to participants who did not. Furthermore, of these participants, only a subset of them may have actually seen the look alike foil they believed to be the perpetrator. Future research should address how witnesses approach the task of choosing foils that look like the perpetrator prior to lineup identification.

We failed to find evidence of improved lineup performance through our mugshot learning task. Several plausible explanations exist for the differences between the current study's results and those of Goodsell, Buttaccio, and Gronlund (2010). The Goodsell et al. study found the benefit only for those participants viewing faces that were similar to

the perpetrator. Although our mugshot photos were chosen to be similar to the perpetrator (see Goodsell et al., 2009 for a more detailed account), it seems likely not all matched the perpetrator to a high degree. Additionally, there could be an optimal number of photos to view beyond which the learning effect yields no benefit and may even start to interfere (the Goodsell et al. participants only judged 6 faces). Finally, it is unclear whether engaging in the learning task well in advance of administering the lineup is beneficial. The benefits of learning likely disappear by the time a participant made his or her lineup identification 48 hrs later. Goodsell et al.'s participants completed the learning task immediately before the lineup identification. Future research will need to investigate these possibilities.

Finally, our results are consistent with prior research on mugshot exposure and suggest that witnesses who are exposed to a mugshot search should not participant in a subsequent lineup identification task. Perhaps developing techniques like the look alike task could allow for both procedures (see also Lindsay et al., 1994). However, until more is understood about the memory and decision making processes involved when witnesses partake in multiple identification procedures it may be best to recommend law enforcement avoid them.

Brewer, Weber, and Semmler (2007) note that theoretical advances regarding eyewitness decision making have been sparse over the past few decades. But the use of computational modeling is one tool that can help us redress this inadequacy (Clark, 2008; Goodsell, Gronlund, & Carlson, 2010; Wells, 2008). Through the use of the WITNESS-ME model, we developed a set of explanations for how eyewitnesses approach a lineup task following mugshot exposure. The application of WITNESS-ME also helped specify

additional questions that need to be addressed by future research. Eyewitness identification always will be fallible. However, the greatest potential for improving techniques lies in capitalizing upon an increased understanding of the processes that underlie eyewitness memory and decision making.

AUTHOR NOTES

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Mathematica code for the perpetrator search, choice included condition can be found in Appendix B.

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Table 1

Lineup Composition for Each Condition

PSCI	PSCNI	LACI	LACNI
Perpetrator Present			
perpetrator	perpetrator	perpetrator	perpetrator
mugshot choice	familiar seen	mugshot choice	familiar seen
familiar seen	4 new foils	familiar seen	4 new foils
3 new foils		3 new foils	
Perpetrator Absent			
mugshot choice	familiar seen	mugshot choice	familiar seen
familiar seen	5 new foils	familiar seen	4 new foils
4 new foils		4 new foils	

Table 2

Proportion of Lineup Choices by Condition

	Control	PSCI	PSCNI	LACI	LACNI	MLN
Perpetrator Present						
Perpetrator	.294	.083	.175	.276	.315	.226
New Foil	.588	.083	.150	.149	.204	.094
Commit	n/a	.695	n/a	n/a	n/a	n/a
Familiar Seen	n/a	.028	.275	.128	.148	.452
Familiar Chosen	n/a	n/a	n/a	.362	n/a	n/a
No ID	.118	.111	.400	.085	.333	.226
Perpetrator Absent						
New Foil	.86	.139	.178	.240	.522	.428
Commit	n/a	.814	n/a	n/a	n/a	n/a
Familiar Seen	n/a	.000	.378	.260	.239	.262
Familiar Chosen	n/a	n/a	n/a	.300	n/a	n/a
No ID	.14	.047	.444	.200	.239	.310

Note. CI = choice included, CNI = choice not included, MLN = mugshot learning.

Table 3

Source Judgments for All Conditions Separated By Type of Lineup Decision

	Choice Included				Choice Not Included			
	CP		CA		CP		CA	
	video	mug	video	mug	video	mug	video	mug
Perpetrator Search Condition								
Commit	*N* = 25		*N* = 35		n/a		n/a	
Commit	4.88	6.16	5.43	6.49				
Fam seen	1.56	3.48	1.46	4.29				
Perpetrator	1.96	3.00	n/a	n/a				
Fam Seen	*N* = 1		*N* = 0		*N* = 11		*N* = 17	
Fam Seen	6.00	3.00			5.72	5.82	5.29	5.41
Commit	1.00	6.00			n/a	n/a	n/a	n/a
Perpetrator	3.00	4.00			1.91	3.55	n/a	n/a
Correct ID	*N* = 3		n/a		*N* = 7		n/a	
Perpetrator	6.00	4.67			5.29	5.71		
Commit	1.00	7.00			n/a	n/a		
Fam Seen	2.33	4.67			3.71	6.00		
No ID	*N* = 4		*N* = 2		*N* = 16		*N* = 16	
Perpetrator	1.00	3.25	n/a	n/a	1.69	4.38	n/a	n/a
Commit	2.00	7.00	3.00	6.50	n/a	n/a	n/a	n/a
Fam Seen	1.00	4.75	1.00	5.00	2.19	4.81	1.95	5.82
Look Alike Condition								
Fam Selected	*N* = 17		*N* = 15		n/a		n/a	
Fam Selected	5.06	5.94	5.20	6.00				
Fam Seen	1.94	3.65	2.2	4.33				
Perpetrator	2.00	2.65	n/a	n/a				
Fam Seen	*N* = 6		*N* = 13		*N* = 8		*N* = 11	
Fam Seen	5.67	4.5	4.31	5.62	4.63	4.00	5.55	4.64
Fam Selected	2.67	5.5	2.15	5.62	n/a	n/a	n/a	n/a
Perpetrator	1.33	4.67	n/a	n/a	2.38	3.88	n/a	n/a
Correct ID	*N* = 13		n/a		*N* = 17		n/a	
Perpetrator	4.83	4.67			4.35	3.88		
Fam Selected	2.00	2.65			n/a	n/a		
Fam Seen	1.85	5.08			2.24	5.24		
No ID	*N* = 4		*N* = 10		*N* = 18		*N* = 11	
Perpetrator	2.25	3.25	n/a	n/a	2.22	3.89	n/a	n/a
Fam Selected	1.00	4.00	2.50	5.40	n/a	n/a	n/a	n/a
Fam Seen	1.50	3.50	2.10	3.80	2.33	4.06	1.27	4.64

Note. PP = Perpetrator present, PA = perpetrator absent. Commit is short for committed foil. Fam is short for familiar.

Table 4

Proportion of Lineup Choices for Mugbook Choosers

	Perpetrator	Commit	Fam Seen	New Foil	No ID
			Perpetrator Present		
Choice Included					
Experiment 1	.083	.695	.028	.083	.111
Goodsell et al. Exp. 1	.095	.649	.041	.080	.135
Choice Not Included					
Experiment 1	.175	n/a	.275	.150	.400
Goodsell et al. Exp. 2	.120	n/a	.160	.120	.600
			Perpetrator Absent		
Choice Included					
Experiment 1	n/a	n/a	.378	.178	.444
Memon et al.	n/a	n/a	.350	.250	.400

Note. Fam is short for familiar.

Table 5

Notation and Model Parameters

Perp	Vector representing the perpetrator
Mem	All Vectors in Memory. Vectors are degraded versions of a target foil (Perp or mugbook foil)
Match	Match value of a particular foil to memory
	Encoding Parameters
mem_c	Encoding parameter indicating the probability each element of the perpetrator will be stored correctly
com_c	Encoding parameter indicating the probably each element of mugshot choice will be stored correctly in memory
mug_c	Encoding parameter indicating the probably each element of the subset of mugshot foils will be stored correctly in memory
	Similarity Parameters
SMP	Similarity between a given mugbook foil and the perpetrator
SFP	Similarity between the lineup foils and the perpetrator
DGS	Degradation of the guility suspect
	Decision Criteria
$crit_{mug}$	Criterion for choosing from the mugbook
$crit_{mc}$	Criterion for making an identification from the lineup for mugbook choosers
$crit_{mnc}$	Criterion for making an identification from the lineup for mugbook non-choosers
crit	Criterion for making and identification from the lineup for no-mugbook participants

Table 6

Parameter Values for the Perpetrator Search Data – Choice Included and Choice Not Included

	mem_c	com_c	mug_c	*SMP*	*SFP*	*DGS*	$crit_{mug}$	$crit_{mc}$	$crit_{mnc}$
Included									
Current study	.13	.60	.45	.10	.25	.70	.062	.125	.110
Goodsell et al. Exp. 1	.13	.45	.15	.10	.25	.70	.068	.108	.148
Not Included									
Current Study	.13	.60	.45	.10	.25	.70	.062	.134	.110
Goodsell et al. Exp. 2	.13	.45	.15	.10	.25	.70	.068	.125	.110

Table 7

Data, Model Predictions, and Fit Statistics for the Perpetrator Search Choice Included Conditions

	Data		Model			Fit	
	PP	PA	PP	PA	choose	*RMSD*	r^2
Experiment 1 – Choice Included							
Mug Chooser						.042	.980
Perpetrator	.083	n/a	.055	n/a	Data		
Commit	.695	.814	.736	.750	.850		
Fam Seen	.028	.140	.096	.113	Model		
New Foil	.083	.000	.032	.051	.851		
No ID	.111	.046	.081	.086			
Mug Non-Chooser							
Perpetrator	.158	n/a	.195	n/a			
Fam Seen	.368	.400	.376	.409			
New Foil	.158	.300	.154	.282			
No ID	.316	.300	.275	.309			
Goodsell et al. (2009, Exp. 1) – Choice Included							
Mug Chooser						.057	.967
Perpetrator	.095		.058	n/a	Data		
Commit	.649		.704	.712	.74		
Fam Seen	.041		.050	.054	Model		
New Foil	.080		.055	.105	.764		
No ID	.135		.133	.129			
Mug Non-Chooser							
Perpetrator	.179		.039	n/a			
Fam Seen	.000		.054	.059			
New Foil	.071		.129	.172			
No ID	.750		.773	.770			

Note. PP = Perpetrator present, PA = perpetrator absent. Choose is the proportion of mugbook choosers.

Table 8

Data, Model Predictions, and Fit Statistics for the Perpetrator Search Choice Not Included Conditions

	Data		Model			Fit	
	CP	CA	CP	CA	choose	*RMSD*	r^2
Experiment 1 – Choice Not Included							
Mug Chooser						.037	.975
Culprit	.175	n/a	.151	n/a	Data		
Fam Seen	.275	.378	.300	.339	.85		
New Foil	.150	.178	.126	.208	Model		
No ID	.400	.444	.423	.453	.874		
Mug Non-Chooser							
Culprit	.158	n/a	.143	n/a			
Fam Seen	.368	.400	.413	.437			
New Foil	.158	.300	.166	.222			
No ID	.316	.300	.278	.341			
Goodsell et al. (2009, Exp. 2) – Choice Not Included							
Mug Chooser						.025	.993
Culprit	.120		.128	n/a	Data		
Fam Seen	.160		.082	.091	.740		
New Foil	.120		.178	.264	Model		
No ID	.600		.612	.644	.726		
Mug Non-Chooser							
Culprit			.062	n/a			
Fam Seen			.069	.066			
New Foil			.084	.186			
No ID			.785	.748			

Note. PP = Perpetrator present, PA = perpetrator absent. Choose is the proportion of mugbook choosers.

Table 9

Data, model predictions, and fit statistics for the Look Alike Condition

	Data		Model		Fit	
	PP	PA	PP	PA	*RMSD*	r^2
			Choice Included			
Perpetrator	.277	n/a	.261	n/a	.067	.646
Fam Selected	.362	.300	.361	.395		
Fam Seen	.127	.140	.115	.140		
New Foil	.149	.240	.178	.340		
No ID	.085	.200	.085	.125		
			Choice Not Included			
Perpetrator	.315	n/a	.293	n/a	.050	.806
Fam Seen	.148	.239	.168	.205		
New Foil	.204	.522	.276	.490		
No ID	.333	.239	.263	.305		

Note. Parameter values for Choice Included: mem_c = .18, com_c =.20, mug_c =.19, $crit_{mc}$ = .07. Parameter values for Choice Not Included: mem_c = .18, com_c =.20 mug_c =.19, $crit_{mc}$ = .085.

APPENDIX A

Mugbook Non-Chooser Data

Table Al

Mugbook Non-Chooser Data

	Perpetrator Present	Perpetrator Absent
Lineup Member		
Perpetrator	.158 (3)	n/a
Familiar Seen	.368 (7)	.300 (3)
New Foil	.158 (3)	.400 (4)
No ID	.315 (6)	.300 (3)

Note. *N* presented in parentheses.

APPENDIX B

```
(* WITNES-ME: Perpetrator Search Choice Included *)

encode = .13;          (*Encoding of Perp*)
dgs = .7;              (*degraded perp*)
cencode = .6;          (*encoding of Committed foil *)
mugencode = .45;       (*encoding to mugphotos into memory *)
cmug = .062;           (*Criterion for choosing from mugbook*)
smp = .1;              (*Similarity of mugbook foils to Perp*)
sfp = .25;             (*Similarity of lineup foils to perp*)
mugsize = 50;          (*mugbook size*)
mccsim = .125;         (*lineup decision criterion – mugbook choosers*)
mnccsim = .11;         (*lineup decision criterion – mugbook non-choosers*)
wa = .5; wr = .5;      (*decision weights*)
ncore = 2;             (*numberof cores*)
nsim = 500;            (* number of simulations per core*)
tsim = ncore*nsim;     (*number of total simulations*)
simdata = Table[0, {k, 2}, {i, 2}, {j, 5}];

(* Goodsell Dissertation data*)

(* Overall Mugshot choosing rate*)   mugchoose = .85;

(*MUGBOOK CHOOSER - TP Lineup*)
(*SUS ID*)             simdata[[1, 1, 1]] = .083;
(*Commit*)             simdata[[1, 1, 2]] = .695;
(*FamSeen Foil*)       simdata[[1, 1, 3]] = .028;
(*New Foil*)           simdata[[1, 1, 4]] = .083;
(*NO ID*)              simdata[[1, 1, 5]] = .111;
(*MUGBOOK NON-CHOOSER - TP Lineup*)
(*SUS ID*)             simdata[[2, 1, 1]] = .158;
(*FamSeen Foil*)       simdata[[2, 1, 3]] = .368;
(*New Foil*)           simdata[[2, 1, 4]] = .158;
(*No ID*)              simdata[[2, 1, 5]] = .316;
```

```
(*MUGBOOK CHOOSER - TA Lineup*)
(*Commit*)              simdata[[1, 2, 2]] = .814;
(*FamSeen Foil*)        simdata[[1, 2, 3]] = .140;
(*New Foil*)            simdata[[1, 2, 4]] = .0;
(*NO ID*)               simdata[[1, 2, 5]] = .046;
(*MUGBOOK NON-CHOOSER TA Lineup*)
(*FamSeen Foil*)        simdata[[2, 2, 3]] = .400;
(*New Foil*)            simdata[[2, 2, 4]] = .300;
(*No ID*)               simdata[[2, 2, 5]] = .300;
wme[] := (
rand[] := RandomReal[{-1, 1}];
ilen = 100;             (*vector length*)
simresp = Table[0, {k, 2}, {i, 2}, {j, 5}];
choosers = Table[0.000001, {i, 2}];
(*k: 1=chooser 2=non-chooser; i: 1=TP 2=TA; j: response options *)
For[isim = 1, isim <= nsim, isim++,

perp = Table[rand[], {i, ilen}];          (*Creates Perp*)
mem = Table[0, {i, 10}, {j, ilen}] ;    (*Empty 10x100 memory vector*)
Do[If[RandomReal[] <= encode, mem[[1, j]] = perp[[j]], mem[[1, j]] = rand[]], {j, ilen}];
(* degraded Perp goes into 1st position in memory*)
lineup = Table[0, {k, 2}, {i, 6}, {j, ilen}]; (*creates empty 6-person PP and PA lineups*)
Do[If[RandomReal[] <= dgs, lineup[[1, 1, j]] = perp[[j]], lineup[[1, 1, j]] = rand[]];
 , {j, ilen}];                                (*perp goes into 1st position in TP lineup*)

(*Lineup foils*)
Do[If[RandomReal[] <= sfp, lineup[[1, i, j]] = perp[[j]], lineup[[1, i, j]] = rand[]];
, {j, ilen}, {i, 3, 6}];                      (* positions 3-6 for PP *)
Do[If[RandomReal[] <= sfp, lineup[[2, 1, j]] = perp[[j]], lineup[[2, 1, j]] = rand[]];
 , {j, ilen}];
Do[If[RandomReal[] <= sfp, lineup[[2, i, j]] = perp[[j]], lineup[[2, i, j]] = rand[]];
, {j, ilen}, {i, 3, 6}];                      (* positions 1, 3-6 for PA *)
```

```
(*Mugbook*)
mugbook = Table[0, {i, mugsize + 1}, {j, ilen}];
                                    (*generates mugbook + fam seen foil in pos 51*)
Do[If[RandomReal[] <= smp, mugbook[[i, j]] = perp[[j]], mugbook[[i, j]] = rand[]];
 , {j, ilen}, {i, mugsize + 1}];

Do[lineup[[k, 2, j]] = mugbook[[51, j]], {j, ilen}, {k, 2}];
                                    (*fam foil goes into 2nd position in BOTH lineups*)

(*Subset of familiar foils into memory*)
Do[If[RandomReal[] <= mugencode, mem[[i, k]] = mugbook[[i, k]], mem[[i, k]] =
rand[]]; , {k, ilen}, {i, 3, 10}];

Do[If[RandomReal[] <= mugencode, mem[[2, k]] = mugbook[[51, k]], mem[[2, k]] =
rand[]]; , {k, ilen}];              (*This places the familiar foil into memory*)
match1 = Table[0, {i, mugsize}];
Do[match1[[j]] = (mem[[1, k]] * mugbook[[j, k]]) + match1[[j]], {k, ilen}, {j,mugsize}];
Do[match1[[j]] = match1[[j]]/ilen, {j, mugsize}];
imax = Drop[Ordering[match1], mugsize - 1]; (*identifies best mugbook member*)

(*Mugshot choosers*)
If[Max[match1[[imax]]] > cmug ,
lineuptype = 1;
choosers[[lineuptype]] = choosers[[lineuptype]] + 1;
Do[If[RandomReal[] <= cencode, mem[[3, k]] = Max[mugbook[[imax[[1]], k]]],
mem[[3, k]] = rand[]];                          (*places mugbook choice in memory*)
lineup[[1, 3, k]] = Max[mugbook[[imax[[1]], k]]];  (*places mc in PP lineup*)
lineup[[2, 3, k]] = Max[mugbook[[imax[[1]], k]]];  (*places mc in PA lineup*)
, {k, ilen}];
];


(*Mugshot non-choosers*)
If[Max[match1[[imax]]] <= cmug,
lineuptype = 2;
choosers[[lineuptype]] = choosers[[lineuptype]] + 1;
];
```

```
 (*Lineup match values*)
Do[Do[match1[[j]] = mem[[i, k]] * lineup[[1, j, k]] + match1[[j]],
{k, ilen},{i,imemsize}]; , {j, 6}];                    (*CP*)

Do[Do[match2[[j]] = mem[[i, k]] * lineup[[2, j, k]] + match2[[j]], {k, ilen},
{i, imemsize}]; , {j, 6}];                             (*CA*)

Do[match1[[j]] = match1[[j]]/ilen, {j, 6}];
Do[match2[[j]] = match2[[j]]/ilen, {j, 6}];
xmax[[1]] = Drop[Sort[match1], 5]; xmax[[2]] = Drop[Sort[match2], 5];
                                                       (* Best matches *)
imax[[1]] = Drop[Ordering[match1], 5]; imax[[2]] = Drop[Ordering[match2], 5];
                                                       (* Position of best match *)
nbest[[1]] = Take[Sort[match1], {5, 5}]; nbest[[2]] = Take[Sort[match2], {5, 5}];
                                                       (* Next best match *)
ev1 = Max[(wa * (xmax[[1]] - nbest[[1]])) + (wr * xmax[[1]])];
ev2 = Max[(wa * (xmax[[2]] - nbest[[2]])) + (wr * xmax[[2]])];


(* simresp 1 = Perpetrator; 2 = Committed foil; 3 = Familiar Seen foil; 4 = New Foil; 5 =
No ID *)

(*PP chooser*)
If[lineuptype == 1,
  If[ev1 > mccsim, makeid1 = 1, makeid1 = -1];
  If[makeid1 == -1, simresp[[1, 1, 5]] = simresp[[1, 1, 5]] + 1];
  If[makeid1 == 1 && Max[imax[[1]]] == 1, simresp[[1, 1, 1]] = simresp[[1, 1, 1]] + 1];
  If[makeid1 == 1 && Max[imax[[1]]] == 2, simresp[[1, 1, 3]] = simresp[[1, 1, 3]] + 1];
  If[makeid1 == 1 && Max[imax[[1]]] == 3, simresp[[1, 1, 2]] = simresp[[1, 1, 2]] + 1];
  If[makeid1 == 1 && Max[imax[[1]]] > 3, simresp[[1, 1, 4]] = simresp[[1, 1, 4]] + 1];
];
(*TA chooser*)
If[lineuptype == 1,
  If[ev2 > mccsim, makeid2 = 1, makeid2 = -1];
  If[makeid2 == -1, simresp[[1, 2, 5]] = simresp[[1, 2, 5]] + 1];
  If[makeid2 == 1 && Max[imax[[2]]] == 1, simresp[[1, 2, 4]] = simresp[[1, 2, 4]] + 1];
  If[makeid2 == 1 && Max[imax[[2]]] == 2, simresp[[1, 2, 3]] = simresp[[1, 2, 3]] + 1];
  If[makeid2 == 1 && Max[imax[[2]]] == 3, simresp[[1, 2, 2]] = simresp[[1, 2, 2]] + 1];
  If[makeid2 == 1 && Max[imax[[2]]] > 3,   simresp[[1, 2, 4]] = simresp[[1, 2, 4]] + 1];
];
```

```
(*TP nonchooser*)
If[lineuptype == 2,
  If[ev1 > mnccsim, makeid1 = 1, makeid1 = -1];
  If[makeid1 == -1, simresp[[2, 1, 5]] = simresp[[2, 1, 5]] + 1];
  If[makeid1 == 1 && Max[imax[[1]]] == 1, simresp[[2, 1, 1]] = simresp[[2, 1, 1]] + 1];
  If[makeid1 == 1 && Max[imax[[1]]] == 2, simresp[[2, 1, 3]] = simresp[[2, 1, 3]] + 1];
  If[makeid1 == 1 && Max[imax[[1]]] > 2, simresp[[2, 1, 4]] = simresp[[2, 1, 4]] + 1];
];

(*TA nonchooser*)
If[lineuptype == 2,
  If[ev2 > mnccsim, makeid2 = 1, makeid2 = -1];
  If[makeid2 == -1, simresp[[2, 2, 5]] = simresp[[2, 2, 5]] + 1];
  If[makeid2 == 1 && Max[imax[[2]]] == 1, simresp[[2, 2, 4]] = simresp[[2, 2, 4]] + 1];
  If[makeid2 == 1 && Max[imax[[2]]] == 2, simresp[[2, 2, 3]] = simresp[[2, 2, 3]] + 1];
  If[makeid2 == 1 && Max[imax[[2]]] > 2, simresp[[2, 2, 4]] = simresp[[2, 2, 4]] + 1];
];

Return[{simresp, choosers}];

)


(* For a dual core machine *)
DistributeDefinitions[wme, ncore, nsim, tsim, encode, dgs, cencode, mugencode,
cmug, smp, sfp, mugsize, mccsim, mnccsim, wa, wr];
ParWme = ParallelEvaluate[wme[]];
Combsimresp = ParWme[[1, 1]] + ParMew[[2, 1]];
Combchooser = ParWme[[1, 2]] + ParMew[[2, 2]];

(*Calculate sum of squared differences*)
ssd = (Combsimresp[[1, 1, 1]]/Combchooser[[1]] - simdata[[1, 1, 1]])^2 +
   (Combsimresp[[1, 1, 2]]/Combchooser[[1]] - simdata[[1, 1, 2]])^2 +
   (Combsimresp[[1, 1, 3]]/Combchooser[[1]] - simdata[[1, 1, 3]])^2 +
   (Combsimresp[[1, 1, 4]]/Combchooser[[1]] - simdata[[1, 1, 4]])^2 +
   (Combsimresp[[1, 1, 5]]/Combchooser[[1]] - simdata[[1, 1, 5]])^2 +
   (Combsimresp[[2, 1, 1]]/Combchooser[[2]] - simdata[[2, 1, 1]])^2 +
   (Combsimresp[[2, 1, 3]]/Combchooser[[2]] - simdata[[2, 1, 3]])^2 +
   (Combsimresp[[2, 1, 4]]/Combchooser[[2]] - simdata[[2, 1, 4]])^2 +
   (Combsimresp[[2, 1, 5]]/Combchooser[[2]] - simdata[[2, 1, 5]])^2 +
```

```
  (Combsimresp[[1, 2, 2]]/Combchooser[[1]] - simdata[[1, 2, 2]])^2 +
  (Combsimresp[[1, 2, 3]]/Combchooser[[1]] - simdata[[1, 1, 3]])^2 +
  (Combsimresp[[1, 2, 4]]/Combchooser[[1]] - simdata[[1, 2, 4]])^2 +
  (Combsimresp[[1, 2, 5]]/Combchooser[[1]] - simdata[[1, 2, 5]])^2 +
  (Combsimresp[[2, 2, 3]]/Combchooser[[2]] - simdata[[2, 2, 3]])^2 +
  (Combsimresp[[2, 2, 4]]/Combchooser[[2]] - simdata[[2, 2, 4]])^2 +
  (Combsimresp[[2, 2, 5]]/Combchooser[[2]] - simdata[[2, 2, 5]])^2 +
  (N[Combchooser[[1]]/tsim] - mugchoose)^2;

(*Data for r2*)
x =
  {Combsimresp[[1, 1, 1]]/Combchooser[[1]], Combsimresp[[1, 1,]]/Combchooser[[1]],
   Combsimresp[[1, 1, 3]]/Combchooser[[1]],  Combsimresp[[1, 1, 4]]/Combchooser[[1]],
   Combsimresp[[1, 1, 5]]/Combchooser[[1]],  Combsimresp[[2, 1, 1]]/Combchooser[[2]],
   Combsimresp[[2, 1, 3]]/Combchooser[[2]],  Combsimresp[[2, 1, 4]]/Combchooser[[2]],
   Combsimresp[[2, 1, 5]]/Combchooser[[2]],  Combsimresp[[1, 2, 2]]/Combchooser[[1]],
   Combsimresp[[1, 2, 3]]/Combchooser[[1]],  Combsimresp[[1, 2, 4]]/Combchooser[[1]],
   Combsimresp[[1, 2, 5]]/Combchooser[[1]],  Combsimresp[[2, 2, 3]]/Combchooser[[2]],
   Combsimresp[[2, 2, 4]]/Combchooser[[2]],  Combsimresp[[2, 2, 5]]/Combchooser[[2]],
   N[Combchooser[[1]]/tsim]};

y =
 {simdata[[1, 1, 1]], simdata[[1, 1, 2]], simdata[[1, 1, 3]], simdata[[1, 1, 4]],
  simdata[[1, 1, 5]], simdata[[2, 1, 1]], simdata[[2, 1, 3]], simdata[[2, 1, 4]],
  simdata[[2, 1, 5]], simdata[[1, 2, 2]], simdata[[1, 2, 3]], simdata[[1, 2, 4]],
  simdata[[1, 2, 5]], simdata[[2, 2, 3]], simdata[[2, 2, 4]], simdata[[2, 2, 5]], mugchoose};
```

```
(*Output*)

Print["Model mug choosers ", N[Combchooser[[1]]/tsim]];

(*Perpetrator Present*)

Print["\n", "MODEL Mugbook Chooser PP "];
Print[
  " Perpetrator: ", N[Combsimresp[[1, 1, 1]]]/Combchooser[[1]],
  " Committed: ", N[Combsimresp[[1, 1, 2]]]/Combchooser[[1]],
  " Familiar Seen: ", N[Combsimresp[[1, 1, 3]]]/Combchooser[[1]],
  " New Foil: ", N[Combsimresp[[1, 1, 4]]]/Combchooser[[1]],
  " No ID: ", N[Combsimresp[[1, 1, 5]]]/Combchooser[[1]]];

Print["DATA Mugbook Chooser PP "];
Print[
  " Perpetrator: ", simdata[[1, 1, 1]],
  " Committed: ", simdata[[1, 1, 2]],
  " Familiar Seen: ", simdata[[1, 1, 3]],
  " New Foil: ", simdata[[1, 1, 4]],
  " No ID: ", simdata[[1, 1, 5]]];

Print["MODEL Mugbook Non-Chooser PP "];
Print[
  " Perpetrator: ", N[Combsimresp[[2, 1, 1]]]/Combchooser[[2]],
  " Familiar Seen: ", N[Combsimresp[[2, 1, 3]]]/Combchooser[[2]],
  " New Foil: ", N[Combsimresp[[2, 1, 4]]]/Combchooser[[2]],
  " No ID: ", N[Combsimresp[[2, 1, 5]]]/Combchooser[[2]]];

Print["DATA Mugbook Non-Chooser PP "];
Print[
  " Perpetrator: ", simdata[[2, 1, 1]],
  " Familiar Seen: ", simdata[[2, 1, 3]],
  " New Foil: ", simdata[[2, 1, 4]],
  " No ID: ", simdata[[2, 1, 5]]];
```

```
(* Perpetrator Absent *)

Print["\n", "MODEL Mugbook Chooser PA "];
Print[
  " Committed: ", N[Combsimresp[[1, 2, 2]]]/Combchooser[[1]],
  " Familiar Seen: ", N[Combsimresp[[1, 2, 3]]]/Combchooser[[1]],
  " New Foil: ", N[Combsimresp[[1, 2, 4]]]/Combchooser[[1]],
  " No ID: ", N[Combsimresp[[1, 2, 5]]]/Combchooser[[1]]];


Print["DATA Mugbook Chooser TA "];
Print[
  " Commit: ", simdata[[1, 2, 2]],
  " Critical Foil: ", simdata[[1, 2, 3]], " New Foil: ", simdata[[1, 2, 4]],
  " No ID: ", simdata[[1, 2, 5]]];
Print["MODEL Mugbook Non-Chooser TA "];
Print[
  " Familiar Seen: ", N[Combsimresp[[2, 2, 3]]]/Combchooser[[2]],
  " New Foil: ", N[Combsimresp[[2, 2, 4]]]/Combchooser[[2]],
  " No ID: ", N[Combsimresp[[2, 2, 5]]]/Combchooser[[2]]];

Print["DATA Mugbook Non-Chooser TA "];
Print[
  " Familiar Seen: ", simdata[[2, 2, 3]],
  " New Foil: ", simdata[[2, 2, 4]],
  " No ID: ", simdata[[2, 2, 5]]];

Print["\n", "\n", "RMSD ", Sqrt[ssd/17]];
Print["rsquared =", (Correlation[x, y]^2)] ;
```