Episodic memory describes memory for events, where an event is defined as an item that occurred in some context. To maintain a coherent record of events encountered, one must successfully store and retrieve information about the event, information about the context of that event, and the binding between the two. How events in episodic memory are bound to information about the context in which they occurred has been investigated using source memory tasks. In a source memory task, participants are typically shown some stimuli (e.g., words, shapes, or objects) which are presented along with contextual information (e.g., the voice of a speaker, location on a display). When cued with the item at a later time, participants are then asked to report the corresponding contextual information.  
 A key question in the source memory literature is whether the retrieval of source information is better characterized as a continuous or a discrete process. Models of source memory as a continuous process, based upon Signal Detection Theory (SDT), predict that

## Non-target Responding

One potential source of error in a memory task involving multiple items, one of which is the target, is that participants motivate their response based on information for the wrong item i.e. a non-target. This tendency for swapping, transposing, or otherwise confusing the identity of items in memory has been observed in a wide array of memory tasks. In the paragraphs to follow, we give a broad review of different types of non-target responding in different memory tasks, and underscore commonalities that offer insight not only into similar behaviour in source memory tasks, but to the general structure of memory retrieval.

In serial recall tasks, where subjects must call lists of items in the sequence in which they are given, a classic finding is that subjects will shift, or *transpose*, the order of items in the list they output. “Locality constraint” (Page & Norris, 1998).

Spatiotemporal transposition gradient (Renko, oberauer). Visual working memory, simulataneous presentation of

In other visual working memory tasks, researchers have observed “swap errors” (Bays)

In cued recall, people make intrusion errors where pairs of items get mixed up with each other

In visual working memory tasks, participants make swap errors. In serial recall, people make transposition errors. In cued recall, people make intrusion responses. What is common across these forms of non-target responding is that the probability of a given non-target item driving a response is influenced by the feature of that item, specifically its similarity in some feature space to the target item.   
**Mechanisms for Generating Non-target responses**

**Models of Intrusions in Continuous-Outcome Tasks**

An influential model of responding in continuous-outcome tasks comes from work in the visual working memory literature, where Zhang and Luck (2008) modelled memory for color stimuli as a probabilistic mixture of two components: 1) a von Mises distribution of errors, centered on the identity of the target item in memory, and 2) a uniform distribution of guesses made when the target item is not in memory. In addition to these two sources of error, Bays et al. (2009) introduced a third possible source of error: a probability that participants report the color of a non-target item, which was represented in the model as additional von Mises distributions centered on each of the color values of the non-target items in the study set. The theoretical importance of this model was that while the two-component Zhang and Luck (2008) model

Previous study of memory for location has found that errors were composed entirely of swap errors, with little evidence of guess responses (Rajsic & Wilson, 2012, 2014; Pertzov et al., 2012). When intrusions between items in the source location task are accounted for in a similar way, the prior research would suggest that the contribution of uniform guesses should be similarly low, and that most errors should arise due to intrusions, or swap errors.

Popov, So and Reder (2021) found that participants make an error due to failing to retrieve a word-location binding, they do not respond with a random non-target. Instead, locations for items presented in closer serial order proximity were more likely than locations for items from further away. This effect of serial order, known as a temporal contiguity effect, has been extensively studied in free-recall paradigms

Another possibility is that swap errors instead reflect strategic guesses, such that in the absence of information about the target, people knowingly use information from a non-target to restrict the range of guesses (Pratte, 2019). In the first instance, the probability of a swap error should be sensitive to factors that increase the confusability of items, namely the similarity between the target and the non-target that intrudes.

In this study, we extend this line of reasoning to consider what experimental factors affect the probability of a non-target generating an intrusion response. At a broad level, as similarity between two items in memory increases, so does confusability and the probability of an intrusion. Previous studies have examined the contribution of similarity in terms of temporal context

With word stimuli, attributes of the words used, such as the semantic and orthographic similarity

Ultimately, our goal in introducing more sophisticated models of intrusion responding is to see to what extent the intrusion component mitigates, or even eliminates, estimations for the proportion of no-information uniform guessing.

# Experiment 1

## Method

### Participants

In Experiment 1, 10 participants were recruited online through the University of Melbourne undergraduate research experience program and 40 participants were recruited via *Prolific*, an online participant recruitment platform. Five participants from the undergraduate pool and seven participants from the Prolific pool did not complete all sessions of the online experiment, resulting in incomplete datasets which were excluded from the final analyses. Additionally, two participants recruited via Prolific were excluded due to at-chance performance in the memory retrieval task, measured by applying the Rayleigh test which indicated no evidence for a departure from uniformity, interpretable as completely random responding. After exclusion, there were five undergraduate participants and 31 Prolific participants, for a total sample of 36 participants. For their participation in each session, undergraduate students were granted credit towards course requirements, and Prolific participants were paid 6.50 GBP/hour. Participants were provided with plain language statements and consent forms and gave informed consent prior to the start of the first session of the experiment.

### Stimuli and Apparatus

Stimuli consisted of words generated from the SUBTLEXus database, filtered for words with a length of four letters, and with frequency ratings between one and five. Words were displayed in size 24 point “Courier New” white font positioned in the center of a uniform mean luminance field. The choice of a monospaced font and the restriction of words to strictly four letters were to ensure stimuli always occupied a consistent amount of space on the screen. Software written in Javascript using jsPsych (deLeeuw, 2015) controlled stimulus presentation and recorded responses.

### Procedure

Participants completed the experimental tasks over three sessions. Each of the three sessions consisted of 120 trials, which was broken up into 12 blocks of ten items each. Blocks consisted of a study phase, a math distractor phase, a recognition phase, and finally a source recall phase. There were additionally five practice trials at the beginning of each session, the data from which was not included for analysis. There were two conditions in this experiment, a simultaneous study condition and a sequential study condition, with all other phases being identical between the conditions. Participants were randomly allocated to either the simultaneous or the sequential presentation condition when beginning session one of the experiment, which would be the same for all subsequent sessions for that participant.

In the sequential study condition, participants were presented with a black marker positioned on a randomly generated angle on the outline of a circle at the start of each trial for 600 ms. The presentation of the marker was followed by the display of a word in the center of the screen for 1500 ms. To ensure that participants attended to the source information, they were instructed to indicate the previous location of the cross on the blank target circle using a computer mouse. Responses made within XX radians of the true target location were classified as attended and advanced participants to the next item. Responses further away were deemed unattended and the words “TOO DISTANT” was displayed for 1000 ms, then the location was then re-presented and the verification task was repeated.

In the simultaneous study condition, participants were presented with the marker and the word simultaneously for 1000 ms. Instead of being positioning the word in the centre of the screen, in the simultaneous encoding condition, the word was positioned at the same angle as the marker, offset by a longer radius. The location of the word relative to the marker was determined by the sector the angle was in, with the word being offset to one of eight points on the bounds of the text box, corresponding to the middle of each of the four sides, and the four corners (i.e. in the North sector, the anchor was the bottom middle of the text box, while in the Northeast sector the anchor was the bottom left of the text box). As with the sequential condition, a verification task followed each presentation, which was repeated until participants reproduced the location to within XX radians of the presented angle.

After studying each of the items for that block, participants were then instructed to complete a distractor task, which involved 30 seconds of arithmetic problems. These problems were presented as three single digit integers, which summed to a fourth number which would either be the correct sum, or a number that was one higher or lower than the actual sum. Participants would indicate if the sum was correct by pressing the keys 0 (false) or 1 (true).

In the recognition phase, participants were shown a shuffled list of 10 previously studied items and 10 foils and asked to rate each item on a six-point Old/New confidence scale. Participants responded by pressing a number from 1 to 6 on their keyboard, with 1 representing “Sure New” and 6 representing “Sure Old”.

Finally, in the source memory retrieval task, participants were cued with the words for 1500 ms, and then indicated the recalled location by a moving the mouse from the starting point in the centre of the circle to a point on the circumference of the response circle. There was no time limit on the decision task. A schematic for one trial in each of the phases is shown in Figure 1.

A picture containing clock

Description automatically generated

Figure 1. Schematic of display presented to the participant in one trial in each phase of the experiment.

## Results

## Discussion

Successive qualitative improvement in fits when intrusion probabilities were determined by temporal and spatiotemporal gradients. However, this was not reflected in quantitative fit statistics, in which marginal improvements in model likelihood with the temporal and spatiotemporal models were outweighed by the additional parameters entailed by those models.

# Experiment 2

## Method

The method for Experiment 2 was identical to Experiment 1 with the following exceptions detailed below.

### Participants

In Experiment 2, participants were recruited solely via Prolific. Of the 10 participants recruited, four participants did not finish all sessions of the experiment, and one participant was excluded as the Rayleigh test indicated no deviance from uniform responding, leaving a final sample of five participants included for the analyses.

### Stimuli

Words were sampled anew from the entire list each time

### Procedure

Only simultaneous presentation. 10 sessions instead of three.

## Results

## Discussion

# General Discussion

## Mixture Models

Ambiguity about the relative contribution of multiple components (i.e. is the decrease in overall intrusion probability over the serial position of the target item associated with an increased probability of the memory component or the guessing component in the model?)

It does not seem reasonable to expect that the proportion of guesses remains the same across serial positions, but we do not have a formal alternative model of guessing. To take an extreme example, we can consider a potential interaction between recognition and intrusion probability where items that are not recognized do not intrude. In a list where no items are recognized, we would intuit that all responses should be guesses.

Need for a process model, like racing diffusion models, to address this ambiguity.