### Schedule

1. לשלוח לרותי abstract ורשימה של 2-3 בוחנים **עד ה30.8.22**.

לכל בוחן לרשום שורה שמסבירה מדוע התחום בו הוא עוסק רלוונטי לתזה שלי.

1. לאחר קבלת אישור לגבי הבוחנים לעדכן את רותי לגבי הבוחנים והתאריך בו קבענו (פירוט לגבי התאריך בסעיף הבא).
2. הבחונים צריכים לקרוא את העבודה ולתת לה ציון לפני המבחן תזה.

צריך לתאם מועד בחינה על תזה עם הבוחנים כדי שיספיקו לקרוא אותה לפני ולשלוח את הפרטים על המועד לרותי **עד ה15.9** (אחרי זה מתחילים החגים ורותי לא זמינה).

המועד לבחינה עד חודש אחרי הגשת העבודה למזכירות במייל.

1. מבחן תזה (הגנת תזה) יכול להיערך **עד ה18.10.**
2. להסדיר במזכירות את כל ההליכים לקראת סיום לימודים **לפני מבחן התזה**.
   1. מילוי חובות לימודים
   2. הגשת עותק של עבודת הגמר חתומה ע"י המנחה (במייל). הבחינה תתקיים **עד חודש אחרי הגשת העבודה**.
3. צריך למלא טופס העלאת התזה לספריה: [טופס הפקדה של עבודת הגמר לתואר שני](https://sagol.tau.ac.il/yedion/987).
4. למלא [טופס הצהרת הסטודנט על מקוריות העבודה](https://sagol.tau.ac.il/yedion/987).
5. לאחר הבחינה וביצוע התיקונים בעבודה, להגיש למזכירות עותק מוגמר של העבודה בדיסק און קי או CD יחד עם טופס אישור העלאה למאגר הדיגיטלי.
6. לאחר מכן יש להזמין טופס טיולים דיגיטלי במערכת מידע אישי לתלמיד.

### Structure

תבנית לעמוד השער של התזה מופיע במייל "הנחיות לקראת סיום התואר, הגשת התיזה והבחינה עליה".

הנחיות כתיבה:

* לא יותר מ-100 עמודים
* רווח 1.5 פונט 12
* מבנה:
  + דף שער - בעברית ובאנגלית בשני צידי העבודה בהתאם לשפה (דוגמאות בסוף המסמך)
  + תקציר - בעברית ובאנגלית בהיקף של 1-2 עמודים בשני צידי העבודה בהתאם
  + תוכן העניינים
  + מבוא - תיאור מלא של מקורות המידע עליהם מסתמך המחקר, הצגת הבעיה הנחקרת ומהי ההצדקה לחקור אותה
  + היפותזה ומטרות המחקר
  + שיטות וחומרים - פירוט החומרים ושיטות העבודה שננקטו במהלך המחקר
  + תוצאות - פירוט תוצאות הניסויים שנערכו ועיבוד התוצאות לצורך הסקת המסקנות
  + דיון - דיון ממצה ומקיף המציין את המסקנות ואת הסימוכין המדעיים המצדיקים את הסקתן
  + סיכום
  + נספחים (איורים וטבלאות) - אם הם אינם בגוף החיבור
  + רשימת מקורות המצוטטים בחיבור. הרשימה תכלול את הפרטים הבאים: שמות המחברים, שם כתב העת, כרך ועמודים.

### Introduction

#### What is unconscious processing

Our brain continuously processes information. It receives inputs via our senses and processes it in various ways, for a variety of stimuli and using different modalities [ref]. For example, upon seeing a ball flying our direction, we process its trajectory and the likelihood of it hitting us. The produced results can lead to a change in behavior – like ducking the ball in this case [ref] – and/or to internal changes, like the induction of fear [ref]. Some of these processes are also accompanied by conscious experiences [ref]: I perceive the flying ball, and I experience the sense of fear. But this is not always the case: I might miss the ball altogether, for example if I am extremely occupied by a different engaging task [ref]. Importantly however , I might still duck the ball following some automated response triggered by unconscious processing [ref]. What differentiates between such conscious and unconscious processing?

In the lab, studies trying to answer this question have used different methods to render the stimulus invisible (for review, see [ref] ). One possibility is to degrade the physical properties of the stimulus (e.g., contrast, resolution, volume, duration) [ref]. Another is to suppress the stimulus by presenting a much more salient stimuli concurrently with the critical stimulus or at close temporal proximity to it (e.g., masking, CFS), hereby rendering it invisible [ref]. Invisibility can also be achieved by diverting attention away from the stimulus [ref].

All three methods, and others (for reviews, see REF) typically decrease the visibility of the stimulus, but also evoke weaker neural responses to the stimulus [ref]. Such weak signals usually translate to small behavioral changes that are hard to detect [ref]. As a result, the field abounds with contradicting findings [ref], which in turn evoke an ongoing controversy about the scope of unconscious processing (ref).

#### Contradicting findings

One point of disagreement concerns the extent of semantic processing without awareness [ref. Among other paradigms, this has often been studied using priming, [ref] where a participant is asked to perform a certain task on a target stimulus. Preceding this target, a related/unrelated invisible prime stimulus is presented. Typically, the subject's response is either facilitated or inhibited according to the congruency between the prime and the target. Such a congruency effect is often taken as evidence the prime was indeed processed (e.g., ref). To ensure that the prime was indeed invisible, an objective and / or subjective measure of prime awareness is typically administered [ref].

While some semantic priming found that invisible words can be processed up to the semantic level, although other studies failed to show semantic effects and claimed that processing only reaches the lexical level [ref]. Moreover, other studies have not found any congruency effects [ref]. Similar controversies involve other types of processing: claims for arithmetic computations being performed without awareness [ref] were challenged by failures to replicate [ref], and a similar mixed picture emerged also for studies of processes like integration [ref].

#### Explaining The discrepancy between findings

How can these contradicting results be explained? One option, that is explored in this thesis, is that they stem from methodological limitations of some of these studies. For example, the way consciousness is measured might strongly affect the obtained results: if the awareness measure is not sensitive enough to discover residual awareness, the researcher might falsely ascribe unconscious processes to conscious processing [ref]. Such insensitivity can stem from several factors: the objective task might probe features of the stimulus that are irrelevant to the tested feature (note that this could also lead to overestimation of awareness; REF) [ref]. In addition, introducing a long delay between the presentation of the stimulus and the awareness measure might cause subjects to forget that they had some experience of it [ref]. Underestimation of awareness can also occur if the subject uses a very strict criterion when judging whether she saw the prime [ref]. Finally, if the objective task is too difficult, subjects can be at chance even if they do see the stimulus, or parts of it, and their motivation to perform the task on invisible stimuli can also be hindered, leading to worse performance [ref].

##### Explaining null findings – Insensitive measures cause unconscious processing under estimation

The above issues might lead to overestimating unconscious processing, due to contamination by conscious effects. On the other hand, one might underestimate unconscious processing, due to insensitive measures of the unconscious effect. The most prominent measure for probing unconscious effects are reaction times (RTs), as measured using keyboard presses (e.g., comparing RTs in the congruent vs. incongruent condition) [ref]. However, for invisible primes this effect is usually very small [ref]. Also, it only indexes the end result of the response, and does not provide insight on the process of formulating the final decision, as it unfolds over time [ref].

#### Motion tracking vs keyboard

Both these problems can be solved using trajectory tracking, which has become a popular tool for unraveling cognitive processes [ref], and might prove to a be a powerful tool for detecting effects evoked by unconscious processes. Contrary to keyboard RTs, which produce a discrete value for each trial, motion tracking provides a continuous set of values which is better suited for tracking ongoing cognitive processes. This was previously used in other fields of research (e.g., unraveling the temporal dynamics of speech comprehension, to show that words are processed in an incremental manner [ref]). Such online tracking of movement as the cognitive processes take place provides further insight on their development over time. For example, when studying syntactic speech processing, researchers used motion tracking to demonstrate that multiple syntactic interpretations of a sentence are processed simultaneously as opposed to serially [ref]. Similarly, motion tracking allows one to compare movement patterns associated with simultaneous conflicting goals and serially occurring goals [ref]. Finally, of the rich, continuous data afforded by motion tracking can be curated for various parameters that are not available when using non-continuous measures, and might reveal an effect that goes unnoticed in the latter case. One such parameter is velocity which was used to inspect subjects' confidence in their answers [ref]. Another parameter is Changes Of Mind (COM), that are not possible to detect when responding with a keyboard, but are reflected in the trajectory when using motion tracking [ref].

#### Prev papers with motion tracking

The ability to unravel cognitive conflicts and observe COM might be beneficial when studying unconscious processing, especially in priming paradigms that evoke conflicts between the prime and target. This was indeed done in a handful of studies: two studies probed the level at which unconscious images are processed by asking subjects to classify a target image preceded by an invisible prime as a person / animal in a reaching response, while movement was tracked. When the prime was incongruent with the target, reaching trajectories tended to deviate towards the incorrect answer [ref], therefore indicating that the semantic meaning of prime images was processed unconsciously [ref]. In a similar experiment digits or letters were primed before classifying a target stimulus as one of them, and here too the trajectories were affected by the congruency between the prime and the target [ref]. Finally, another study used motion tracking to demonstrate the role of attention in facilitating priming [ref]: subjects were asked to judge a target digit as larger or smaller than 5, and exhibited longer reach trajectories when this target was preceded by an incongruent prime (compared to a congruent one), and this effect was larger when the subjects attended to the prime [ref].

#### Prev papers with motion tracking and keyboard

Thus, motion tracking can be used to unravel unconscious processing as it unfolds. But are these effects indeed stronger than keyboard-RT ones? This question has hardly been studied. Two studies combined motion tracking and keyboards RTs, yet without directly comparing between them. In the first, keyboard responses were affected by prime-target congruency, and motion tracking showed that it also affected the ongoing execution of the motor response. This served as basis for the conclusion that the motor response is based on feedforward processing that is first evoked by the prime, and then corrected once the target becomes available [ref]. In the second study, the effects of unconscious processing in the dorsal stream were tested. Alongside the keyboard-RT effect, motion tracking was held to index dorsal – as opposed to ventral – processing, under the assumption that reaching movements are more heavily dependent on dorsal processing than button presses [ref].

#### Xiao + reaching vs mouse

To date, only one study directly compared the strength of the effects revealed by keyboard presses and motion tracking [ref]. The authors concluded that positive / negative primes facilitate a same / different response accordingly when participants judge the similarity of two digits. Critically, this effect was marginally significant when probed with a keyboard, but robust when measured via mouse tracking. Although this study indeed reinforces the above assumption, according to which motion tracking might be beneficial for unraveling unconscious processes, it also suffers from several limitations. First, awareness assessment was done in a separate block after the main task, with no online assessment of prime visibility on a single trial level. This is especially important since the visibility ratings of many participants were above zero, suggesting that the effect might have been driven by some conscious processing. In addition, performance was not tested against chance, and instead shown not to correlate with the congruency effect – a method that has been widely criticized [ref]. Finally, the number of trials in the awareness task was XX, which might be underpowered for detecting awareness [ref].

Other than specifications of the awareness measure worthy of note is also the unintuitive semantic relation between the valence of the primes and the same / different response.

Notably, this study used mouse tracking and not reaching movements, which might be less sensitive. Using a mouse requires subjects to remap the real-world representation into 2D. Such 2D mapping constrains free movement [ref], which can affect the trajectory and timing of the movements [ref] and suppress the expression of cognitive conflicts. Indeed, when both measures were compared, reaching produced shorter movement durations, larger curvatures, faster velocities and most importantly, it responded faster to changes of mind [ref]. Reaching movements are also more intuitive than using a mouse, making them less effortful and possibly more likely to express fluctuations in the decision [ref]. These properties accordingly suggest that reaching movements might be optimal for detecting fast and short-lasting processes such as unconscious priming effects [ref].

#### Current Research

The current study was aimed at testing the above hypothesis that motion tracking might be superior to the commonly used keyboard responses measure in detecting effects of unconscious processing. This was tested in a series of four studies, with rigorous awareness measures to ensure residual awareness is not mistaken for unconscious processing. Three exploratory studies were aimed at finding the optimal conditions for discovering an unconscious effect when using reaching responses. A fourth confirmatory study directly compared between motion tracking and keyboard responses as a means to examine if one measure has an advantage over the other. All four studies used a priming paradigm following a classical study by Deheane and colleagues [ref], in which subjects were presented with a masked prime word followed by a visible identical/different target word. This task was chosen as it was supposed to evoke strong effects, in a fairly simple design which probes identity priming. They were asked to perform a semantic judgment on the target word, and determine if it describes a natural or artificial item. In the first three experiments, I expected to find evidence for a congruency effect with motion tracking, so that reaching trajectories are. In the fourth experiment, I expected to find a larger congruency effect in the motion tracking task than in the keyboard task.

### Exp 1

The first experiment's purpose was to produce a first dataset to experiment with. The end goal was to troubleshoot the experiment and the motion tacking system and establish an encapsulating analysis environment that can extract meaningful parameters from the recorded trajectories. We were hoping to locate a congruency effect in at least one of the parameters and tweak the experiments that followed to maximize its size (e.g., change the RT or training length).

#### Methods

##### Participants

Ten participants (8 females) between the ages of eighteen and thirty-five were recruited for the study (M = 24.2, SD = 2.57). All participants were right-handed, native Hebrew speakers who have normal vision or corrected-to-normal vision. Only participants declaring that they have no neurological, attentional, or mental disorders, and are not taking psychiatric medicines, were included. All participants signed a consent form and were explained that they can stop the experiment at every point if they wished to do so. They were reimbursed with course credit or cash payment. The experiment was approved by the Tel Aviv University ethics committee.

##### Stimuli

One hundred 5-letter words were used as primes and targets. All words were imageable nouns with a frequency of at least 10 per million [ref]. One half described artificial products (e.g., radio, train) and the other natural items (e.g., fruit). Target words were written in typescript while prime words were written in handwriting font. Masks were composed of a semi-random combination of squares and diamonds whose line thickness is equal to the word's font size and which covers the central area of the screen where words can appear (approximately ). Forty words were used for the practice block and the remaining sixty were used in the test blocks.

##### Apparatus

The stimulus was displayed on a VPIXX monitor (VIEWPixx /3D Lite LCD display and data acquisition system, version 3.7.6287) using Matlab R2020b [ref] and Psychtoolbox 3.0.18 [ref]. The monitor was set to full brightness at a resolution of 1920 x 1080 and refresh rate of 100Hz with VPIXX's "Scanning backlight" feature turned on, which synchronizes the stimulus display to the screen's refresh rate. A Perspex cover was placed over the screen to protect it. The cover was spray painted with a light layer of transparent matte lacquer to avoid reflections. The participants sat approximately 60cm away from the screen and placed their index finger on a marked starting point located on the table 40cm away from the screen, in line with its center. The stimulus was displayed 24cm above the table and the classification answers were displayed on each side of it, 20cm apart (Figure 6). Participants wore a Velcro ring with a marker at the tip of their index finger. A touch was registered when the marker was 3cm away from the screen or closer. A system of 6 OptiTrack Flex 13 cameras by NaturalPoint, Inc. tracked the marker's location using Motive 2.3.0 software [ref] at a sampling rate of 120Hz. The coordinates were broadcasted online to a NatNet client [ref] and recorded with Matlab.

A picture containing text, device

Description automatically generated

Figure 1. Setup. A participant placing his finger on the starting point which is located 40cm away from the screen. The target is positioned 24cm above the starting point and the answers are placed on each of its sides, 20cm apart. Z axis maps the path to and from the screen. X axis maps the left and right directions. Y axis maps the up and down directions.

##### Procedure

Each session included a practice block and twelve test blocks of forty trials each (i.e., 40 practice trials and 480 test trials). Breaks were given between blocks. Half the trials were congruent and half incongruent, and half the targets were natural and half artificial. Stimuli order in the experimental blocks was dictated by a list that was randomly sampled (without replacement) out of ten pre-composed lists of trial condition and stimulus. An additional practice list was used for all participants. In each list, the order of words was pseudorandom, with the following constraints: (a) Each word was equally frequent as a target at the congruent and incongruent conditions; (b) All words were used as targets the same number of times; (c) A target never repeated in the same block; (d) In the congruent condition the prime was identical to the target word; (e) In the incongruent condition, a prime which doesn't share letters in common locations with the target was selected from the alternative category (artificial/natural). For example, in the congruent condition, the word "phone" could be preceded by "PHONE", while in the incongruent condition it could be preceded by "GRASS". Each prime was further paired with a random distractor from the same category (artificial/natural) to be used in the prime recognition task. The distractor shared no letters in common locations with the prime, so seeing one letter only sufficed for correct discrimination.

The procedure closely followed the one used in Dehaene et al. [ref], yet in a motion tracking setup. Every trial consisted of a fixation cross (1000ms), a first mask (270ms), a second mask (30ms), a prime word (30ms), a third mask (30ms) and a target (500ms). Once the target was displayed, participants classified the target word as describing a natural / artificial item by reaching the side of the screen that contains the appropriate category (Figure 7). Responses had to be provided within a 1500ms time window from target presentation. Movement duration was defined as the time between target onset and the point when the finger was 3cm away from the screen or closer (on the Z axis). Responses slower than 1500ms were followed by a "Move faster" feedback. After Classifying the targets, the participants were asked to recognize the prime as an objective measure of prime awareness. Participants were presented with two words – the prime and another word from the same category. Response was given in an identical fashion to the target classification task, within a 5 seconds response window. Finally, a subjective measure of prime awareness was taken, using the Perceptual Awareness Scale (PAS) [ref]. Participants used the keyboard numbers 1-4 to rate how well did they see the prime (1 – "Didn't see anything", 2 – "Saw something vaguely, but can't say what it is", 3 – "Saw part of the prime clearly", 4 – "Saw the whole prime clearly"). Finally, participants were asked to return their finger to the starting point.

Diagram

Description automatically generated

Figure 2. Stimuli presentation order of experiment one. Each trial was composed of a fixation cross (1000ms), a first mask (270ms), a second mask (30ms), a prime word (30ms), a third mask (30ms), a classification task (0-1500ms, out of which the target was displayed for 500ms), a recognition task (0-5,000ms) and a PAS task (no time limit). The blue circles appearing on the screen are presented as markers for the subjects to know where they should touch in order to make their response.

##### Trajectory preprocessing

The preprocessing procedures followed those described in Gallivan & Chapman [ref]. Missing values were interpolated with the inpaint\_nans function (D’Errico, 2022) to fill gaps in the trajectory, which was then filtered with a low pass butterworth filter (2nd order with cutoff at 8Hz) to reduce noise. The axis' origin was set at the first sample of each trial. To locate reaching onset, a low pass butterworth filter (2nd order with a 10Hz cutoff) was applied to the 3D velocity. *Reaching onset* was indicated by four consecutive samples having a velocity greater than 20mm/s and a total acceleration of at least 20mm/s^2. *Reaching offset* was determined as the point along the trajectory that is closest to the screen. The trajectories were normalized to the total distance traveled along the axis perpendicular to the screen (Z axis). To do so, a B-spline of the 6th order with a roughness penalty on the 4th derivative was fitted to each axis with a spline at every data point. The fitted function was used to produce a high-resolution representation of the trajectory (1000 samples) from which 200 points equally spaced along the total traveled distance on the Z axis were extracted (e.g., if the participant moved 2cm forward and 1cm backward, the total distance that was traveled was 3cm). These points represented the proportion of path traveled until each point.

##### Variables extraction

The congruency effect was estimated with eight reaching parameters: (a) reach area, defined as the area confined between the average trajectory to the left side when the correct answer is on the left and the average trajectory to the right when the correct answer is on the right; (b) reaction time, defined as the time from stimulus presentation up to movement onset. Movement onset and movement offset are distinguished from reaching onset and offset. *Movement onset* is detected once the Euclidean distance from the starting point is greater than 2cm. Movement offset is recognized once the distance from the screen on the Z axis is shorter than 3cm; (c) movement duration, defined as the time from movement onset until the screen is reached; (d) deviation from center, defined as the distance of every point along the average trajectory from the center line, which is a line drawn between the starting point and the middle of the screen; (e) movement variation, defined as the standard deviation of the "Deviation from center" measure. The standard deviation was computed over the trials; (f) heading angle, defined as the angle confined between a tangent at every point along the trajectory and a line perpendicular to the screen. An angle was considered negative if the extension of the tangent met the screen on the side opposite to the chosen answer; (g) changes of mind, defined as the number of changes in implied goal along a single trial's trajectory. The implied goal was indicated by the side where the current tangent to the trajectory meets the screen; (h) total distance traveled, defined as the sum of Euclidean distances between the samples of a single trial.

##### Exclusion criteria

Trials in which either a technical malfunction occurred, or a problematic response was given, as well as trials that had a visibility rating that is higher than one, were excluded from the analysis. A technical malfunction signifies trajectories that had less than 100ms of existing data or more than 100ms of missing data, or trials in which the stimuli duration was incorrect. Problematic responses include incorrect answers and trajectories that missed the target by more than 12cm, as well as reaching movements that were shorter – when measured along the z axis – than the distance between the starting point and the screen, minus a three-centimeter allowance that accounts for small variations in reaching onset. Finally, slow movements were disqualified if they were located more than 3 SD from the average movement duration across the participant's correctly answered trials that did not have missing data.

#### Results

The responses to the recognition task on the congruent condition do not represent the objective visibility since the prime and target words are identical which biases the responses. Therefore, only the responses in sthe incongruent condition were used to estimate prime visibility. When participants rated the prime as invisible, they were not better than chance at recognizing it, M = 50.6%, SD = 3.4, t(9) = 0.59, p = 0.56, 95% CI = [48.2, 53]. The total distance traveled on the congruent (M = 1.01, SD = 0.006) and incongruent (M = 1.01, SD = 0.007) conditions did not differ (t(9) = -0.94, p = 0.36, 95% CI [-0.003, 0.001], Cohen's dz = -0.29) and neither did the COM frequency (Mcon = 0.21, SDcon = 0.06, Mincon = 0.2, SDicon = 0.08, t(9) = 0.3, p = 0.76, 95% CI [-0.03, 0.04], Cohen's dz = 0.09). Reach area was marginally smaller in the incongruent condition (Mcon = 0.028, SDcon = 0.0047, Mincon = 0.027, SDincon = 0.0050, t(9) = 2.22, p = 0.053, 95% CI [-0.00001, 0.0021], Cohen's dz = 0.703) while reaction time was marginally longer in the incongruent condition (Mcon = 0.433sec, SDcon = 0.125, Mincon = 0.441sec, SDincon = 0.125, t(9) = -2.075, p = 0.067, 95% CI [-0.016, 0.0007], Cohen's dz = -0.656). Movement time didn't differ between the conditions (Mcon = 0.558sec, SDcon = 0.08, Mincon = 0.557sec, SDincon = 0.081, t(9) = 0.077, p = 0.93, 95% CI [-0.069, 0.007], Cohen's dz = 0.024). The permutation and clustering procedure produced 1 significant difference in the deviation from center, 3 in the SD of the deviation from center and 6 in the heading angle.

#### Discussion

### Experiment 1 was conducted to establish an experimental environment capable of capturing unconscious effects with motion tracking. In contrast to our expectations, no robust unconscious effect was found in any of the motion tracking measures, and although a trend was found in some of them, it was never significant. Nevertheless, this trend was most prominent in the reach area variable, which implies it might be the optimal variable for probing the unconscious effect. Interestingly, although the movement duration was similar in both conditions, there was a trend to longer reaction times in the incongruent condition. This pattern of results might imply that the conflict created by the prime in the incongruent condition is resolved before the movement starts which might explain why an unconscious effect was hardly seen.Exp 2

For an unconscious effect to be reflected in the reaching trajectories, the conflict that it produces has to be present while the reaching is performed. The longer movement time for incongruent trials in experiment one implied this was not the case. Therefor in experiment two, movement onset was restricted and movement duration was decreased.

Since quicker responses were required a second training block was added. The results were expected to reflect a greater unconscious effect than experiment one seeing that an overlap should exist between the decision making process and the reaching movement.

#### Methods

##### Participants

Fourteen participants (10 females) were recruited for the study (M=24.78, SD=3.68) in a recruitment procedure identical to experiment 1. Five subjects were disqualified from the analysis since three of them had less than 25 valid trials in each condition [ref to exclusion criteria of exp 2] and the other two performed significantly worse than 70% correct answers in the classification task according to a binomial test.

##### Stimuli

Stimuli was identical to that used in experiment one.

##### Apparatus

The set up was identical to that used in experiment one except that the starting point was 35cm away from the screen and the size of the blue circle beneath each target was slightly increased so that hitting it will be easier.

##### Procedure

In this experiment before performing the practice and test blocks, the participants completed an initial practice block that did not include a prime. The order of trials in this block was drawn from an additional list of trial condition and stimulus. Other than that, all the lists were the same. Timing was also adjusted so that movements had to start before 330ms had passed and last no longer than 430ms. Movement started when the finger was 2cm away from the starting point (Euclidean distance) and ended when it was 3cm away from the screen (on the Z axis). Late initiations and long durations were followed by a "Too late" and "Too slow" feedbacks respectively. Recognition responses were given within a 7 second response window. The rest of the design was identical to experiment one.

Diagram, schematic

Description automatically generated

Figure 2. Stimuli presentation order of experiment 2. Each trial was composed of a fixation cross (1000ms), a first mask (270ms), a second mask (30ms), a prime word (30ms), a third mask (30ms), a classification task (0-760ms, out of which the target was displayed for 500ms), a recognition task (0-7,000ms) and a PAS task (no time limit). The blue circles appearing on the screen are presented as markers for the subjects to know where they should touch in order to make their response.

##### Variables extraction

Movement onset and movement offset were defined differently than in experiment 2, as here……

are distinguished from reaching onset and offset. *Movement onset* is detected once the Euclidean distance from the starting point is greater than 2cm. Movement offset is recognized once the finger is 3cm away from the screen on the Z axis.

##### Exclusion criteria

The criteria for excluding trials was identical to that used in experiment one, with a few additional criterions: movements that started less than 100ms or more than 320ms after target display were excluded. In addition, movements that lasted more than 420ms were excluded if they were located more than 3 SD from the participant's average movement duration among correct trials that were not too short, had no missing data and were completed in time (i.e. started between 100ms and 320ms after target display and lasted no longer than 420ms).

#### Results

When participants rated the prime as invisible, they were not better than chance at recognizing it, M = 50.2%, SD = 2.57, t(8) = 0.30, p = 0.77, 95% CI = [48.27, 52.24]. Similarly to experiment one a congruency effect was not reflected in the total distance traveled (t(8) = -0.83, p = 0.42, 95% CI [-0.008, 0.003]), frequency of COM (t(8) = -0.4, p = 0.69, 95% CI [-0.11, 0.07]), reaction time (t(8) = -1.192, p = 0.26, 95% CI [-0.011, 0.003]) or movement duration (t(8) = -1.192, p = 0.26, 95% CI [-0.021, 0.006]). Contrary to experiment one, the difference between the reach area in the congruent (M = 0.00015sec, SD = 0.0000289) and incongruent (M = 0.00013sec, SD = 0.0000646) conditions, t(8) = 0.667, p = 0.523, 95% CI [-0.0000281, 0.0000511], Cohen's dz = 0.222, was far from significant. The average number of valid trials (that were not excluded due to any reason) among included and excluded participants was 91.64 (SD = 57) out of 240 in the congruent condition and 84.57 (SD = 54.8) out of 240 in the incongruent condition. On average, 118 trials were excluded due to late response and 31 due to early response, while 67 trials were excluded due to incorrect answer.

#### Discussion

The congruency effect was expected to be larger in experiment two since prime dilution was diminished by further limiting the subjects response time. However, none of the dependent variables showed any difference between the conditions, including reach area which was marginally significant in experiment one. This contradicting finding might be settled by taking into consideration a single participant whose results were in the opposite trend to the rest. Another explanation for the lack of effect could be the difficulty in performing the task in the given timing constraints. On average, 118 trials were disqualified due to late responses and 31 due to early responses. The quick response might also bring about wrong answers, which on average account for 67 of the excluded trials.@@@ Perhaps mention single subjects results and show that the trajectories of some of did deviate in the expected direction @@@

### Exp 3

A high number of excluded trials reduces the power of the analysis and could explains why significant effects were not found in experiment two. Many of these trials were excluded due to bad timing which indicates the task's timing requirements were too difficult for the participants. Therefor in experiment three a practice day was held before the test day aiming to improve the subjects' response time. Once the response time improves the task should become easier and therefore we expected to see less incorrect answers.

#### Methods

##### Participants

Thirteen participants (XX females) were recruited for the study (M=XX, SD=XX) in a recruitment procedure identical to experiment 1. Six subjects were excluded from the analysis since one of them had less than 25 valid trials [ref to exclusion criteria] in each condition and the other five performed significantly worse than 70% correct answers in the classification task according to a binomial test.

##### Stimuli

Sixty 4-letter words were used as primes and targets on the practice day. All words followed the same criteria as in the previous experiments. The stimuli on the test day remained the same as in the previous experiments.

##### Procedure

The participants completed six practice blocks on the practice day, whose structure was indetical to the test blocks used in previous experiments, except that the stimuli order was drawn from a new set of ten lists of trial and stimuli order. Restrictions on movement onset and duration were reduced by 10ms to 320ms and 420ms respectively, and an additional "Too early" feedback was given if the participants responded before 100ms has passed since target presentation. The minimal movement onset limitation was intended to prevent predictive responses, i.e., responses that are planned and executed before the stimuli is processed and hence might lead to incorrect answers.

#### Results

When participants rated the prime as invisible, they were not better than chance at recognizing it, M = 47.4%, SD = 3.4, t(6) = -1.94, p = 0.1, 95% CI = [44.26, 50.65]. Contrary to experiment two, a congruency effect was reflected in shorter traveled distance in the congruent (M = 1.01, SD = 0.005) than in the incongruent condition (M = 1.02, SD = 0.007), t(6) = -3.76, p = 0.009, 95% CI [-0.008, -0.001], Cohen's dz = -1.422. In accordance with shorter movements, movement duration was also marginally shorter in the congruent (M = 0.39, SD = 0.03) than in the incongruent condition (M = 0.4, SD = 0.025), t(6) = -2.41, p = 0.051, 95% CI [-0.022, 0.0001], Cohen's dz = -0.91. On the other hand frequency of COM (t(8) = -0.4, p = 0.69, 95% CI [-0.11, 0.07]) and reaction time (t(6) = -2.22, p = 0.067, 95% CI [-0.02, 0.001]) did not differ between the conditions. Reach area was significantly larger in the congruent (M = 0.0002, SD = 0.00003) than in the incongruent condition (M = 0.0001, SD = 0.00002), t(6) = 3.02, p = 0.02, 95% CI [0.000006, 0.00004], Cohen's dz = 1.14. The average number of valid trials among included and excluded participants was 87.61 (SD = 34.69) out of 240 in the congruent condition and 77.84 (SD = 36.23) out of 240 in the incongruent condition. The total number of valid trials did not differ significantly between experiment three and two (t(25) = -0.3, p = 0.76, 95% CI [-83.5, 62](. Non significant trends were noticed when analyzing each exclusion reason separately. The amount of late responses decreased (M3 = 118, SD3 = 128.16, M2 = 52.84, SD2 = 30.83, t(25) = -1.78, p = 0.08, 95% CI [-140.4, 10]), while the number of short trajectories (M3 = 57, SD3 = 40.7, M2 = 18.5, SD2 = 18, t(25) = 3.2, p = 0.003, 95% CI [13.8, 63.1]), slow movements (M3 = 77.5, SD3 = 44.3, M2 = 60, SD2 = 50.4, t(25) = 0.95, p = 0.34, 95% CI [-20.3, 55.2]), early responses (M3 = 54.3, SD3 = 50.6, M2 = 31.5, SD2 = 36.5, t(25) = 1.35, p = 0.18, 95% CI [-11.9, 57.6]), and incorrect answers (M3 = 91.2, SD3 = 57.13, M2 = 67, SD2 = 36.1, t(25) = 1.32, p = 0.19, 95% CI [-13.4, 61.7]) increased.

Show the analysis that compares the end of block 1 and the end of block 6 in day 1, to show RT improved (did you check the num of incorrect answers, if so, describe this change as well).

#### Discussion

You should interpret the results here or in previous experiments: smaller reach area means the subjects were biased towards the incorrect answer. Longer movement time means the movement was conflicted, and so does longer trajectory.

Talk about the fact that late responses descreased while early and wrong responses increased, so the participants were more focused on answering quickly than answering in time and correctly.

### Exp 4

The first experiment used a rather long RT restriction which was later reduced and divided to onset time and movement duration in the second experiment. In addition, the second experiment also introduced another training block to improve response speed. The third experiment incorporated a whole separate training day to achieve the same goal but was then discarded in the fourth experiment as it caused an "over training" effect.

### General Discussion

This paper claims averaging trajectories is wrong. Read it before the thesis test:

Wulff (2019). Mouse-tracking: Detecting types in movement trajectories

Check if this paper has some conclusions about "reaching" that can be relevant for your discussion:

Schmidt (2007). Measuring unconscious cognition: Beyond the zero-awareness criterion

Convert all movement duration and reaction time results to ms.

Things to do before sending to Liad:

* Make sure "movement onset" is used only when describing the analysis, while movement initiation of beginning of movement is used when describing the timing limitations ("Too Early"). Do the same for offset.