Papers for to look for other papers inside:

* Read: "Does unconscious perception really exist? Continuing the ASSC20 debate",

Check if contains ref to papers about controversy or criticism.

* Read: Do we have Unconscious Perception? (in downloads folder).

Chapter 2 contains criticism about awareness measures while chapter 3 criticizes the performance measures.

* Thesis criticizing UC perception.

**Also go over papers you already read and summed –** you can start from "Papers I Read", you have been through the

stuff before.

**Reviews**

Kouider S, Dehaene S, Jobert A, Le Bihan D (2007) Cerebral bases of subliminal and supraliminal priming during reading.

* Rohr, M., & Wentura, D. (2021). Degree and Complexity of Non-conscious Emotional Information Processing–A Review of Masked Priming Studies

Kouider 2007 - Levels of processing during non-conscious perception a critical review of visual masking

Hedger et al. (2016). Are visual threats prioritized without awareness? A critical review and meta-analysis

Gambarota et al. (2022). Unconscious Visual Working Memory: a critical review and Bayesian meta-analysis

Tamietto, M., and DeGelder, B. (2010). Neural bases of the non-conscious perception of emotional signals

van der Ploeg et al. (2017). Peripheral physiological responses to subliminally presented negative affective stimuli

McNamara, T. P. (2013). “Semantic memory and priming,”

Herring et al. (2013). On the automatic activation of attitudes: a quarter century of evaluative priming research

Klauer et al. (2009). Contrast effects in spontaneous evaluations: a psychophysical account

Van Opstal, F. (2021). The same-different task as a tool to study unconscious processing

**Behavioral evidence for UC processing**

* Van den Bussche, E., Van den Noortgate, W., & Reynvoet, B. (2009). Mechanisms of masked priming: a meta-analysis

Kiesel, A., Kunde, W., Pohl, C., Berner, M. P., & Hoffmann, J. (2009). Playing chess unconsciously

Abrams RL, Klinger MR, Greenwald AG (2002) Subliminal words activate semantic categories (not automated motor responses)

Ferrand L, Humphreys GW, Segui J (1998) Masked repetition and phonological priming in picture naming

Finkbeiner M, Forster K, Nicol J, Nakamura K (2004) The role of polysemy inmasked semantic and translation priming

Forster KI, Davis C (1984) Repetition priming and frequency attenuation in lexical access

Grainger J, Cole P, Segui J (1991) Masked morphological priming in visual word recognition

Devlin, J. T., Jamison, H. L., Matthews, P. M. & Gonnerman, L. M. 2004 Morphology and the internal structure of words

Naccache, L. & Dehaene, S. 2001b The priming method: imaging unconscious repetition priming reveals an abstract representation

Devlin, J. T., Jamison, H. L., Matthews, P. M. & Gonnerman, L. M. 2004 Morphology and the internal structure of words

Leuthold H, Kopp B (1998) Mechanisms of priming by masked stimuli Inferences from event-related brain potentials.

Bahrami B, Lavie N, Rees G (2007) Attentional load modulates responses of human primary visual cortex to invisible stimuli. Current Biology 17: 509–513.

Dehaene S, Naccache L, Cohen L, Le Bihan D, Mangin JF, et al. (2001) Cerebral mechanisms of word masking and unconscious repetition priming

Henson RN, Mouchlianitis E, Matthews WJ, Kouider S (2008) Electrophysiological correlates of masked face priming.

Kouider S, de Gardelle V, Dehaene S, Dupoux E, Pallier C (2010) Cerebral bases of subliminal speech priming.

**Brain evidence for UC processing**

Nakamura, K., Dehaene, S., Jorbert, A., Le Bihan, D. & Kouider, S. 2005 Subliminal convergence of Kanji and Kana words: further evidence for functional parcellation of the posterior temporal cortex in visu

Kiefer, M., & Brendel, D. (2006). Attentional modulation of unconscious “automatic” proc

Devlin, J. T., Jamison, H. L., Matthews, P. M., & Gonnerman, L. M. (2004). Morphology and the internal structure of words

Scepticism about Unconscious Perception is the Default Hypothesis (Not sure if for or against UC processing)

On scepticism about unconscious perception (Not sure if reviews enough papers).

Neural capacity limits during unconscious semantic processing (EEG evidence for unconscious semantic processing)

Kouider, S., Dehaene, S., Jobert, A. Cerebral bases of subliminal and supraliminal priming during reading

Kiefer M, Brendel D (2006) Attentional modulation of unconscious ‘‘automatic’’ processes: Evidence from event-related potentials in a masked priming paradigm

**Criticism regarding UC processing findings**

* The Validity of d′ Measures
* A task-difficulty artifact in subliminal priming
* Reexamining unconscious response priming: A liminal-prime paradigm
* Shanks DR. Regressive research: the pitfalls of post hoc data selection in the study of unconscious mental processes
* Do semantic priming and retrieval of stimulus-response associations depend on conscious perception?

Congruity effects evoked by subliminally presented primes: Automaticity rather than semantic processing

Priming of awareness or how not to measure visual awareness

Criterion problem:

Eriksen CW (1960) Discrimination and learning without awareness: a methodological survey and evaluation

Hannula DESimons DJCohen NJ (2005) Imaging implicit perception: promise and pitfalls

Lloyd DAAbrahamyan AHarris JAAntal A (2013) Brain-stimulation induced blindsight: unconscious vision or response bias

Merikle PSmilek DEastwood JD (2001) Perception without awareness: perspectives from cognitive psychology

Bjorkman, M., Juslin, P. & Winman, A. 1993 Realism of confidence in sensory discrimination: the

underconfidence phenomenon

Human observers have optimal introspective access to perceptual processes even for visually masked stimuli: - it mostly criticizes using only subjective measure, without objective measure. They conclude that if objective measure is above chance, the subject is aware of the stimulus.

look for: " imply complete lack of awareness, only that the stimulus"

Phillips, I. 2016. Consciousness and criterion: on Block’s case for unconscious seeing:

look for: " we need to consider seriously the possibility that the response"

Holender, D. (1986). Semantic activation without conscious identification in dichotic listening, parafoveal vision, and visual masking: a survey and appraisal

Kunimoto, C. Miller, J. & Pashler, H. Confidence and accuracy of near-threshold discrimination responses

Wolfe, J. M. in *Fleeting Memories: Cognition of Brief Visual Stimuli*

**Criticism regarding UC processing in general**

Look here for criticism on each method, look also in its citations? (How can we measure awareness?

An overview of current methods)

Look in its citations as well (Subliminal or not? Comparing null-hypothesis and Bayesian methods for testing subliminal priming)

Reversed Priming Effects May Be Driven by Misperception Rather than Subliminal Processing

Problems in using d' measures to assess subjective awareness

Prior conscious experience enhances conscious perception but does not affect response priming

Lau H. Are we studying consciousness yet?

Aru J, Bachmann T, SingerWet al. Distilling the neural correlates of consciousness

Hannula DE, Simons DJ, Cohen NJ. Imaging implicit perception: promise and pitfalls

Merikle PM, Smilek D, Eastwood JD. Perception without awareness: perspectives from cognitive psychology

Vadillo et al. (2016) Underpowered samples, false negatives, and unconscious learning

Merikle, P., and Reingold, E. (1992). “Measuring unconscious perceptual processes,” in Perception Without Awareness:

Schmidt, T. (2015). Invisible stimuli, implicit thresholds: why invisibility judgments cannot be interpreted in isolation

Lähteenmäki et al. (2015). Affective processing requires awareness

**Weak signals in UC**

Does unconscious perception really exist? Continuing – didn’t read

A Meta-Analysis on Unconscious Thought Effects – didn’t read

~~Mechanisms of Masked Priming: A Meta-Analysis~~ – They don't show a small effect (avg for semantic categorization is

0.8). But in their data prime visibility is correlated with UC effect, so these studies should be taken with a grain of salt regarding the UC part of them.

They do show that for word primes, avg effect size is 0.51.

* Greenwald paper (1998 Science) – Greenwald, A. G., et al. (1996). "Three cognitive markers of unconscious

semantic activation." Science 273(5282): 1699-1702.

Maybe here:

Replicable unconscious semantic priming

Distinguishing unconscious from conscious cognition—Reasonable assumptions and replicable findings: Reply to Merikle and Reingold (1998) and Dosher (1998)

Correcting for measurement error in detecting unconscious cognition: Comment on Draine and Greenwald (1998)

Klauer et al. (2007). Priming of semantic classifications by novel subliminal prime words – dz = 0.3-1.2.

Can the meaning of multiple words be integrated unconsciously

Mudrik - Neuroscientific evidence for processing of unconscious information.docx (in my papers)

* Neural correlates of subliminal language processing

Decoding the meaning of unconsciously processed words using fMRI-based MVPA

Neural evidence for non-conscious working memory

Learning of goal-relevant and -irrelevant complex visual sequences in human v1

~~Brain mechanisms underlying the brief maintenance of seen and unseen sensory information~~ subjects are aware

**null results due to non-sensitive measure**

track it to crack it – Liad recommends just finding an advantage for motion tracking over RT in general (not necceseraly

in th UC domain).

**controversy in the field**

* Does unconscious perception really exist? Continuing
* Unconscious perception and phenomenal coherence
* Do semantic priming and retrieval of stimulus-response associations depend on conscious perception?
* Unconscious perception reconsidered
* Number processing outside awareness? Systematically testing sensitivities of direct and indirect measures of consciousness

Papers of: Hakwan Lau, Megan Peters and Ian Phillips

Naccache et al. (2002) Unconscious masked priming depends on temporal attention

Abrams et al. (2002). Subliminal words activate semantic categories (not automated motor responses).

Sand, A. (2016). Reversed priming effects may be driven by misperception rather than subliminal processing

Klapp et al. (2005). Nonconscious influence of masked stimuli on response selection is limited to concrete stimulus-

Ortells et al. (2016). The semantic origin of unconscious priming: Behavioral and event-related potential evidence during congruency priming from strongly and weakly related masked words – can't find this paper.

Taylor, H. (2020). Fuzziness in the mind: Can perception be unconscious?

Berger et al. (2019). On scepticism about unconscious perception

Berger et al. (2021). Default hypotheses in the study of perception: A reply to Phillips

Michel, M. How (not) to underestimate unconscious perception

Merikle, P. M., & Daneman, M. (1998). Psychological investigations of unconscious perception

Fowler, C., Wolford, G., Slade, R., & Tassinary, L. (1981). Lexical access with and without awareness

Schmidt, T., and Vorberg, D. (2006). Criteria for unconscious cognition: three types of dissociation

Lähteenmäki, M., Hyönä, J., Koivisto, M., and Nummenmaa, L. (2015). Affective processing requires awareness.

Holender, D., & Duscherer, K. (2004). Unconscious perception: the need for a paradigm shift

Merikle, P. M. (1992). Perception without awareness: Critical issues

Reeset al. (2002). Neural correlates of consciousness in humans

**Motor costs affect decision making**

Cos, I., Belanger, N., & Cisek, P. (2011). The influence of predicted arm biomechanics on decision making ---- Motor costs affect decision making.

## Send Liad all the papers so she can read abstracts on plane.

Add titles to figures and explanations of what you see underneath them. And mention them in the text.

Make sure citations in the comments in the introductions look good and doen't have nonsense written about some of them.

Ask liad if the figures should be made differently to look more formal?

## Introduction

The scope of unconscious processing is highly controversial [REF]. Although unconsciously processed stimuli have been repeatedly shown to evoke both behavioral and neural changes [REF], some of these findings have been criticized on different grounds [REF] and are generally not easy to detect given the typically weak signals [REF]. A prominent complication stemming from this difficulty to detect unconscious effects relates to the most appropriate interpretation for such findings. For example, small positive effects can be attributed to the use of a non-exhaustive awareness measure (i.e., contamination by aware processes) [REF], while null results can be attributed to the use of a non-sensitive performance measure [REF]. Such contradicting interpretations make the field highly debated [REF].

The goal of our research is accordingly to look for ways to enhance the measured signals and obtain robust effect sizes. We thus examine the usage of motion tracking as a performance measure, and ask if it is superior to the widely-used keyboard response and response time (RT) measure. Continuous motion tracking allows to capture fluctuations in the decision as it formulates [REF] and hence is used in studies to uncover cognitive conflicts stemming from an unconscious stimulus [REF]. However, the only direct comparison made between motion tracking and keyboard response could have benefited from more strict awareness measures and a more natural response method [REF]. Our experiment will keep a rigorous awareness test as well as utilize the intuitive nature of reaching responses.

Since intuitive response measures require less effort to use they increase the tendency for the expression of decision fluctuations in the trajectory. Ergo, the propensity for the expression of unconscious effect increases [ref].

[ref] and the probability for the expression of unconscious effects is increased. In previous motion tracking pilots, we found an effect size larger than those found in similar experiments conducted with a keyboard. Accordingly, in this direct comparison, we expect to find an advantage for motion tracking over keyboard responses.

### Hypothesis

We hypothesis motion tracking will be more sensitive to cognitive conflicts than a keyboard response. Therefore, we expect the congruency effect found when using motion tracking to be larger than that found while using a keyboard response.

## Methods

### Design

IV:

1. Congruency – A within subject variable of two levels.
   1. Congruent: prime and target are the same word.
   2. Incongruent: Prime and target are a different word from a different semantic category that do not share letters in common locations.
2. Response measure – A within subject variable of two levels.
   1. Motion tracking: The participant chooses an answer by reaching and touching it on the screen.
   2. Keyboard response: The participant chooses an answer by pressing "E" / "Y" accordingly.
3. Item type – A within subject variable of two levels. Item type is manipulated duringthe task but is not a variable of interest for the analysis.
   1. Natural: target and / or prime describe a natural item (e.g., "Plant", "Cloud").
   2. Artificial: target and / or prime describe an artificial product (e.g., "Radio", "Phone").

DV:

1. *Reach area:* Measures the effect in the "Reaching" session as the area between a participant's average path to the left target and the average path to the right target in a single condition (congruent / incongruent). The path will be averaged across trials in each condition.

Chart, funnel chart

Description automatically generated

Figure 1. Depiction of reach area. The dark and light red lines represent a single participant's average trajectory to the left and right accordingly. The pink area represents a single participant's reach area.

1. *Response time:* Measures the effect in the "Keyboard" session as the time it takes a participant to classify the target as natural / artificial. It is defined as the time from target presentation up until "E" / "Y" are pressed.

Exploratory DV:

Figure 2.Depiction of area under the curve (AUC) depiction. The red line represents a single trial's path and the grey line represents the theoretical "Optimal path" for that trial. The pink area represents the positive and negative area under the curve. A/B represent the target on the left/right side accordingly.

1. *Reaction time:* From stimulus presentation up to movement initiation. Movement initiation is detected once the Euclidean distance from the starting point is greater than 1cm.
2. *Movement time:* From movement initiation until the screen is reached.
3. *Maximal absolute deviation:* the point along the trajectory that is furthest away from the optimal path for that trial.

Diagram

Description automatically generated

Figure 3. Depiction of maximal absolute deviation (MAD). The red line represents a single trial's path while the grey line represents the "optimal path" for that trial The black arrow represents the maximal absolute deviation of the trial's path from the "optimal path".

1. *Deviation from center:* Distance of every point along the average trajectory from the center line (a line connecting the starting point and the middle of the screen).

Chart

Description automatically generated

Figure 4. Depiction of Deviation from center. Each red dot represents a single sample along the movement trajectory. The dashed grey line represents the center line and the blue arrows represent each sample's deviation from the center.

1. *Movement variation:* Standard deviation of the "Deviation from center". The standard deviation will be computed for each participant over all the valid trials in each condition.
2. *Changes of mind (COM):* The frequency of goal changes during a movement. Will be measured by

,

Number of changes in implied goal (the side, left/right, where the current tangent to the trajectory meets the screen).

1. *Total distance traveled:* The sum of Euclidean distances between samples along the trajectory of a single trial.

Chart

Description automatically generated

Figure 5. Depiction of total distance traveled. Each red dot represents a single sample along the movement trajectory and the grey arrows represent the Euclidean distance between each pair of consecutive dots. The sum of the grey arrows is the total distance traveled.

### Planned sample

All participants will be right-handed, native Hebrew speakers who aren't color blind and 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, will be included.

Data will be collected at Prof. Liad Mudrik's lab for high level cognition in Tel-Aviv University, from students or other young adults at the ages of 18-35, in a 90 minutes session.

Participants will be reimbursed with course credit or cash payment.

### Sample size estimation

The semantic priming effect of the reaching task was estimated in two pilots ran in the lab. The average effect sizes was Cohen's dz = 0.88. In accordance with our hypothesis we assume the keyboard task's effect size will be around 30% smaller (Cohen's dz = 0.61). To discover such effect with a power = 95% and we require a sample of 30 participants [ref].

### Exclusion criteria

The following trials will be excluded from the main analysis:

1. Trials with visibility rating higher than 1.
2. Trials in which there was a technical malfunction with the setup or recording:
   1. Over 100ms of missing samples in the trajectory.
   2. Less than 100ms of existing samples in the trajectory.
   3. Stimulus presentation duration deviated from the desired by more than 2ms.
3. Trials in which the participant provided a problematic response:
   1. Short reach distance: The extent of the processed trajectory as measured on the *Z* axis from the point furthest away from the screen to the point closest to it was shorter than:

"Marker gap" accounts for the variating distance of the marker from the edge of each participant's finger and its value is 0.7cm.

* 1. Missed targets: Touching point on screen is more than 12cm away from either target.
  2. Bad timing: In the keyboard task, key press was too early (less than 200ms after target), or too late (more than 740ms after target). In the reaching task, movement started too early (less than 100ms after target display, implying a planned response) or too late (more than 320ms after target display).

Slow reaching movements (reaching duration was longer than 420ms) will be included in the analysis if they are within 3 STD from the average reaching time of the participant.

* 1. Wrong answer when classifying the target.
  2. No response given via the keyboard.

Participants will be excluded according to the following criteria:

1. Less than 25 valid trials in each condition (congruent / incongruent).

"Valid" trails are those that have a PAS rating of 1 and weren't excluded due to any of the above reasons.

1. Failed to classify the target correctly on at least 70% of the trials that were completed in time (i.e. not "Too early" or "Too late")..
2. Recognized the prime correctly on more than 50% of all incongruent trials.
3. "Reach area" larger than 0.07m2 Fig [ref]. Such value is highly unlikely and will thus indicate incorrect execution of the experiment or a problem with the recording.

A picture containing text, device

Description automatically generated

Figure 6. Depiction of the maximal reach area. This figure presents a hypothetical situation that will produce a very large reach area. This will occur if a participant first moves in the direction of the chosen answer (left / right) and then advances toward the screen. The red lines represent this participant's average paths to the left and right targets and the pink area represent the large reach area that is defined as the maximal reach area.

### Apparatus

The stimulus will be displayed on a VPIXX monitor (VIEWPixx /3D Lite LCD display and data acquisition system, version 3.7.6287) using Matlab [ref] R2020b (9.9.0.14677003) and Psychtoolbox 3.0.18 – Flavor: beta, Corresponds to SVN Revision 12779. The monitor will be 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 will be placed over the screen to protect it. The cover will be spray painted with a light layer of transparent matte lacquer to avoid reflections. The participants will sit approximately 60cm away from the screen and place their index finger on a marked starting point which will be located on the table 35cm away from the screen, in line with its center. The stimulus will be displayed 24cm above the table and the classification answers will be displayed on each side of it, 20cm apart. Participants will wear a Velcro ring with a marker at the tip of their index finger. "Marker gap" defines the maximal distance of the ring from the fingertip and will be set to 0.7cm. A system of 6 OptiTrack Flex 13 cameras by NaturalPoint Inc will track the marker's location using Motive 2.3.0 software [ref] at a sampling rate of 120Hz. The coordinates will be broadcasted online to a NatNet client [ref] and recorded with Matlab.

Diagram

Description automatically generated

Figure 7. Setup. A participant placing his finger on the starting point which is located 35cm 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.

### Materials and stimuli

**Stimuli Selection**

One hundred 5-letter words will be used as primes and targets. All words will be imageable nouns with a frequency of at least 10 per million [ref](Cite: <http://word-freq.mscc.huji.ac.il/>). One half will describe artificial products (e.g., radio, train) and the other natural items (e.g., fruit). Target words will be written in typescript while prime words will be written in handwriting font. Masks will be 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 will be used for the practice blocks and the remaining Sixty for the test blocks.

### Procedure

Each participant will perform a "Reaching" session and a "Keyboard" session, and their order will be counterbalanced across participants.

Each session will include a practice block and six test blocks of Forty trials each (i.e., 40 practice trials and 240 test trials per session, 560 trials total). Breaks will be allowed between blocks. Throughout the experiment, half the trials will be congruent and half incongruent, and half the targets will be natural and half artificial. Stimuli order will be dictated by two lists that will be randomly sampled (without replacement) out of twenty pre-composed lists of trial condition and stimulus. One list will be assigned to the "Reaching" session and the other to the "Keyboard" session. The practice lists will be drawn in a similar fashion out of a different set of 10 lists. In each list, the order of words is pseudorandom, with the following constraints: (a) Each word is equally frequent as a target at the congruent and incongruent conditions; (b) All words are used as targets the same number of times; (c) A target never repeats in the same block; (d) In the congruent condition the prime is identical to the target word; (e) In the incongruent condition, a prime which doesn't share letters in common locations with the target is selected from the alternative category (artificial/natural). For example, in the congruent condition "phone" can be preceded by "PHONE", while in the incongruent condition it can be preceded by "GRASS". Each prime is further paired with a random distractor from the same category (artificial/natural) to be used in the prime recognition task. The distractor shares no letters in common locations with the prime, so seeing one letter only would suffice for correct discrimination.

The procedure closely follows the one used in Dehaene et al., [REF]. Every trial will consist 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 is displayed, participants will classify the target word as describing a natural / artificial item by selecting the side of the screen that contains the appropriate category. In the "Reaching" condition the participants will touch the appropriate side of the screen. Here, responses are bound to onset time and movement time constraints; Onset is the time from target presentation until the participant's finger moved 1cm away from the starting point (Euclidean distance). It must be longer than 100ms to prevent predictive movements but shorter than 320ms to prevent prime dilution. Inaccurate timing will be immediately replied with a "Too Early" / "Too Late" feedback accordingly. Movement time starts once the finger leaves the starting point and ends when the participant is 0.7cm away from the screen (on the Z axis). Movements longer than 420ms will be replied with "Too Slow" feedback once they are completed. In the "Keyboard" condition participants will use "E"/"Y" keys to select the left / right side accordingly. Response must be given within a time window of 250-740ms from target display; otherwise "Too Early" / "Too Late" feedback is given. After Classifying the targets, the participant will be asked to recognize the prime as an objective measure of prime awareness. Participants will be presented with two words – the prime and another word from the same category. Response will be given in an identical fashion to the target classification task, within a 7 seconds response window. Finally, a Subjective measure of prime awareness will be taken, using the Perceptual Awareness Scale (PAS) [ref]. Participants will use 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, in the "Reaching" session participants will have to return their finger to the starting point after each response.

Diagram, schematic

Description automatically generated

Figure 8. Design. Stimuli presentation order. Each trial starts is composed of a fixation cross (1000ms), a first mask (270ms), a second mask (30ms), a prime word (30ms), a third mask (30ms), a categorization task (100-740ms out of which the target is displayed for 500ms), a recognition task (100-7000ms) and a PAS task (no time limit).

## Analysis plan

### Trajectory preprocessing

The preprocessing procedures will follow those described in Gallivan & Chapman (2014). Missing values will be interpolated with the inpaint\_nans [REF] function to fill gaps in the trajectory, and will then be filtered with a low pass butterworth filter (2nd order with cutoff at 8Hz) to reduce noise. The axis' origin will be set at the first sample of each trial. To locate movement onset, a low pass butterworth filter (2nd order with a 10Hz cutoff) will first be applied to the 3D velocity. Onset will be indicated by four consecutive samples having a velocity greater than 2mm/s and a total acceleration of at least 2mm/s^2. Offset will be determined as the point along the trajectory that is closest to the screen. The movements will be normalized to the traveled distance 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 will be fitted to each axis with a spline at every data point. The fitted function will be used to produce a high-resolution representation of the trajectory (1000 samples) from which 200 points equally spaced along the total distance traveled on the Z axis will be extracted (e.g., if the participant moved 2cm forward and 1cm backward, the total distance traveled is 3cm). These points will represent the proportion of path traveled.

### Dependent variables extraction

#### Reach area calculation

The area will be calculated in three stages. First, a line perpendicular to the screen will be established at the lowest X value. Then the area between each average trajectory and that line will be computed. The results will be subtracted from each other, and their absolute value will be used as the reach area. To avoid negative area values, the trajectories will be split at their intersections and the area will be calculated separately for each section.

Diagram

Description automatically generated

Figure 9. Reach area calculation. The average trajectories of a participant to the right (light red) and left targets (dark red) are produced. Then a line perpendicular to the screen (black) is plotted at the minimal X value among both trajectories. The area between each trajectory and that line is computed and the results are subtracted from each other giving the participant's reach area.

### Confirmatory analysis

A paired t-test will be conducted between the congruent and incongruent conditions for each DV. Multiple comparisons will be corrected for using the Tree-BH method [ref] based on the tree structure described in Fig [ref]. The "effectsize" package [ref] will be used to evaluate Cohen's dz and its confidence intervals.Non overlapping confidence intervals will indicate an advantage for one measure over the other. In the event that a different DV will produce a larger effect size, it will be used instead of "Reach area".

Chart, radar chart

Description automatically generated

Figure 10. Tree-BH architecture. Nodes represent statistical tests. Deviation from center and STD of x have multiple points for each trial, therefore a permutation and clustering procedure is used to extract the significant clusters, and only those will be included in the exploratory analysis.

The normality of the difference score of each DV will be examined with a qq-plot and a violation will necessitate the use of a t-test with permutation to estimate the congruency effect. Outliers located more than one and a half inter quartile ranges from the average reach area or keyboard RT prohibit the use of a paired t-test. Will this occur, a robust t-test will be conducted using R's WRS2 package [ref] and its "APK" effect size will used instead of Cohen's dz.

### Expected results

In the reaching task, we expect to find a bias for the incorrect answer in the incongruent condition. A tendency to deviate toward the side opposite to the final correct answer will increase the total distance traveled, the AUC and the maximal absolute deviation from the optimal path but decrease the deviation from the center. The bias will also curve the average path towards the center which will make the reach area smaller.

In addition, an incongruent prime will evoke a cognitive conflict which is expected to increase the time it takes to reach a final decision. This will manifest in longer movement time as well as in higher movement variation.

In the keyboard task, we expect longer reaction times in the incongruent condition.

Finally, we expect effect sizes to be larger in the reaching task than in the keyboard task.

### Project data collection

Start and end dates @TBD@