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Utilizing Fitts' Law to Examine Motor Imagery of Self, Other, and Objects

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UTILIZING FITTS' LAW TO EXAMINE MOTOR IMAGERY OF SELF, OTHER, AND OBJECTS

by

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ABSTRACT

Past research has indicated that motor imagery, or imagined movement, follows Fitts' law similarly to physical movement. Additionally, motor imagery has been shown to improve real motor performance in multiple contexts, showcasing a remarkable connection with real motion. The current study examines how the subject of motor imagery, imagining oneself, another person, or an object, impacts this faithfulness to real movement, specifically in following Fitts' law. Participants viewed 2D photos of a virtual environment with an "X", a humanoid, or a disc facing a gate at 6 distances and 4 widths for 24 combinations. Each combination was repeated twice randomly for 48 trials per condition, and conditions were presented in random order for a total of 144 trials. Results indicate that object-imagery does trigger motor imagery and follow Fitts' law, in contrast to prior research. However, further analysis showed that the function produced in the object condition was significantly different from both self and other, while self and other were not significantly different from one another. This was due to a higher index of performance value in the object condition, implying that participants assigned the object different abilities than the two human-centered conditions. These results indicate a difference related to biological, or perhaps human, motion, and future studies should further explore the impact of the subject and characteristics of the subject on motor imagery. Understanding these intricacies is crucial to refine and understand the benefits of motor imagery seen in multiple motor performance contexts.

Keywords: Fitts' law, motor imagery, motor performance

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The field of Psychology is constantly evolving. One change that has occurred in recent years is the coupling of perception and action. This was not always the case, as perception and action were siloed in different research areas for decades. On one side, sensation and perception research was heavily influenced by Helmholtz's theory of unconscious inference (1867). This rested upon the assumption that we must rely on cognitive processes to enrich and interpret the visual information relayed from the eyes (Wilcox & Katz, 1984). The Helmholtzian view of perception is unnecessarily separated from the outside world, and in light of modern research, from the action-generation process (Warren, 2006). Likewise, old theories of motor control tended to lack a connection to perception research. Peripheral motor control and feed-forward control, or open loop, theories are an example of this. Peripheral motor control refers to actions outside of the central nervous system and conscious awareness, contained mostly to a local area, and often considered an isolated action, in this way minimizing the role of perception (Schmidt, 1975). Schmidt takes a cognitive top-down view, changing the role of perception to that of post-action evaluation, in other words only evaluating whether the action was a success after the fact, rather than adjusting during an action (closed-loop system). Later theorists argue that examining perception or action alone is insufficient to explain behavior (Reed, 1982). The evolution of research surrounding Fitts' law highlights this initial disconnect, as well as the growing sentiment that action and perception are inseparable.

The following sections cover Fitts' law, motor imagery (MI), and their interplay, as well as how the perception of others can help us to clarify what makes MI possible. The current study will examine the role of motor imagery (MI) in perception and action research, setting out to test the hypothesis that the aspects of MI that connect it to real movement, represented by adherence to Fitts' law, are specific to biological motion, and do not occur when engaging in imagery of an object moving.

Fitts' Law

Pioneered by Paul Fitts in the 1950s, Fitts' law describes the tradeoff of speed and accuracy in a pointing task where participants are instructed to move as fast as possible while remaining accurate. Fitts discovered that there is a lawful relationship between the movement time and the index of difficulty (ID), calculated by dividing twice the distance to target by target size, and taking the log base 2 of the result: ID = $\log_2$ (2*distance/width) (Fitts, 1954). This speed-accuracy tradeoff is one of the most consistent phenomena in psychology. In fact, Fitts' law is incredibly consistent. It's been replicated in walking tasks, pointing with a computer mouse, and imagined pointing and walking tasks (Bakker et al., 2007; Bohan et al., 2010; Decety & Jeannerod, 1996). This lawfulness makes it an ideal testing ground for observing the coupling of perception and action. One scenario that has the potential to reveal more about Fitts' law and perception-action coupling in general is motor imagery, or the mental simulation of action, separating the motor plan from the action itself. If motor imagery, a perceptual process, reflects Fitts' law, this would clearly identify perception as a key constraint leading to Fitts' law, rather than it being solely a peripheral motor process.

Motor Imagery and Fitts' Law

Multiple studies support the claim that Fitts' law applies to motor imagery in a variety of scenarios. Early examples of this include Decety and Jeannerod's (1996) study, where participants were asked to imagine walking toward gates at varying apparent distances and widths in virtual reality, and these mentally simulated actions abided by principles of Fitts' law. Imagined walking tasks are not the only context where Fitts' law appears in motor imagery, as it is reflected in a variety of imagined movements. (Guillot & Collet, 2005). In real pointing tasks, a consistent anomaly in Fitts' law has been found where the last target in an array does not produce a movement time (MT) significantly longer than the previous target as predicted (Radulescu et al., 2010). Radulescu et al. proposed that if this error occurs during the "planning stage" of the movement then it should be reflected in motor imagery, as the act of simulating the movement is similar to planning. Their experiment bore this out, showing that motor imagery does not seamlessly follow Fitts' law, but reflects errors found in real movement (Radulescu et al., 2010). Bakker et al. (2007) provided more evidence of the connection between real movement and motor imagery, having participants perform a walking task across a wooden beam—in this case, the width of the beam served as the target size constraint rather than gate width—and imagining this same task using a two-dimensional image of the same environment. They found that motor imagery again reflected real movement. Also of interest was a third condition: imagining a disc moving across the beam. Their results showed that imagining this disc is different than imagining oneself walking, as it did not follow Fitts' law, specifically the effect of beam width (Bakker et al., 2007). Bakker et al. used this to distinguish "motor imagery", or actually engaging in the mental simulation of the action and thus engaging similar parts of the brain as movement and resulting in its faithfulness to Fitts' law, from "visual imagery", or simply imagining an object moving. This shows that motor imagery specifically entails the perception of human movement kinematics involved in the task, rather than just simple feed-forward movement to a target. If motor imagery reflects the acquisition of perceptual knowledge, it will hold for other people. In contrast, if it reflects running these top-down simulations, then it is not perceptual, and would not predict that we would have sensitivity to other's movements.

Perception of Others

A key distinction in perception is the perception of self or other. If motor imagery reflects the kinematics of one's own movement, then it may also hold for the movement of others. Humans rely heavily on the perception of others in order to learn, whether that is complex behavior or simple motor skills (Bandura, 1962). Research has suggested a potential neural basis for this ability in the form of mirror neurons (Rizzolatti, 2005), which may further aid in understanding the difference between motor and visual imagery. Motor imagery can also be used as a tool for individuals to learn or practice movements, improving motor performance (Saimpont et al., 2013). Examples include athletes training (Guillot & Collet, 2008), patients rehabilitating and thus unable to physically practice (Lebon et al., 2012; Moukarzel et al., 2019), and older adults working to regain or maintain motor skills (Nicholson et al., 2018). Motor imagery of oneself can also be used to practice and acquire skills, following real motion closely enough to abide by Fitts' law. The perception of others leads to learning. What about motor imagery of others? Would mentally simulating someone else's movement reflect the same movement dynamics as simulating one's own? Action and perception are intimately linked, as demonstrated by motor imagery mirroring many properties of action, and if observing others' actions triggers similar brain areas as performing that action, simulating others' actions should be connected to simulating one's own movement. Thus, motor imagery of others should abide by Fitts' law, as self-motor imagery does.

Properties of Others

Also of interest is what characteristics of others impact motor imagery. In Bakker et al.'s study (2007), imagining an inanimate object moving, specifically a disc, did not follow Fitts' law and thus did not seem to activate motor imagery. In predicting that imagining another person moving will result in motor imagery, but not an object, we are implying that motor imagery is in part tied to biological motion, and not simply motion of any kind.

Hypotheses

If the hypothesis that Fitts' law reflects the coupling of perception and action processes is supported, and if it is further the case that motor imagery reflects this coupling, then we expect to find that self-motor imagery will follow Fitts' law, consistent with the prior observations of Bakker et al. (2007). Further, if perception of others reflects the same learning of movement kinematics as observation of self-motion, then we also expect that other-imagery trials will follow Fitts' law. Finally, based on the conclusions of Bakker et al. (2007), we expect that imagining object movement is unrelated to perception and action and will not reflect Fitts' law, and thus visual imagery of a non-humanoid object will not follow Fitts' law.

Methods

Participants

Participants were all University of Central Florida (UCF) students, recruited through SONA, the Psychology department's online platform to sign up for studies. The experiment was fully online through Pavlovia (Ilixa, Ltd.) and Qualtrics and took an approximate average of 33 minutes to complete. All participants were awarded extra credit which could be used in their Psychology courses at UCF.

Materials

Virtual Environment

A virtual environment (VE) was created in order to capture 2D images for use in this study. The VE was created in Unreal Engine 4 (UE4; Epic Games, Inc.) and displayed various objects or marks at an identical starting point facing target gates at varying distances (3, 6, 9, 12, and 15 meters) and widths (0.4, 0.6, 0.8, and 1.0 meters), resulting in ID's ranging from 2.59 to 6.50. This range of ID values was chosen to include a range of both easy and difficult targets, while also avoiding gate widths smaller than a typical person's shoulders. The environment resembled a clearing in a forest, with trees in the background but no distracting objects between the starting point and the gate (see Appendix A). The path between the starting point and the gate resembled a walking path, while the surrounding area is covered in grass. For the self-imagery condition, there was an 'X' marking the starting point, for the other-imagery condition there was a humanoid agent, and for the object-imagery condition there was a simple object (similar to a disc as in Bakker et al., 2007).

Humanoid Agent

The humanoid agent used in the other-imagery condition is a slightly altered version of the UE4 mannequin used in Sasser (2019), a humanoid robot with no facial features, of medium build and proportion (see Appendix B). The agent was shown facing away from the participant and towards the target (see Appendix A).

Surveys and Scales

Demographic scale. Participants were asked to provide background information such as gender and age. At the end of the trials, participants provided their height, weight, and shoulder width (if they could not measure exactly, they were asked to estimate as either small, medium, or large). Warren and Whang (1987) found that shoulder-width impacted the size door that participants believed they could pass through without adjusting their angle, with the critical point coming at a ratio of 1.3 (width of the door to shoulder width), so if individual variations in shoulder width show differential movement times, we can detect this.

Honesty questions. Participants were asked if they completed the study truthfully, and told that they would not be penalized if they reported that they did not. They were also asked what method they used to imagine movement, with the intent to exclude anyone who attempted to count steps or employed some other heuristic that did not entail imagining a movement, as in Bakker et al. (2007).

Godspeed Series Questionnaire. The Godspeed series anthropomorphism sub-scale (5 items, 5 point Likert scale, see Appendix C) was used (Bartneck et al., 2009). This series is used in human-robot interaction (HRI) research to measure the perceived human-like characteristics of a robot or virtual agent. Given that we assume that properties of the humanoid agent may impact participants' judgments of movement, we used this instrument to evaluate if participants' perceived anthropomorphism impacted their attribution of human movement.

Vividness of Visual Imagery Questionnaire (VVIQ). The VVIQ (16 items, 5 point scale) was used to measure a participant's ability to conjure clear mental images (Marks, 1973; see Appendix D). Individual differences in this ability may impact performance or otherwise account for variance.

Procedures

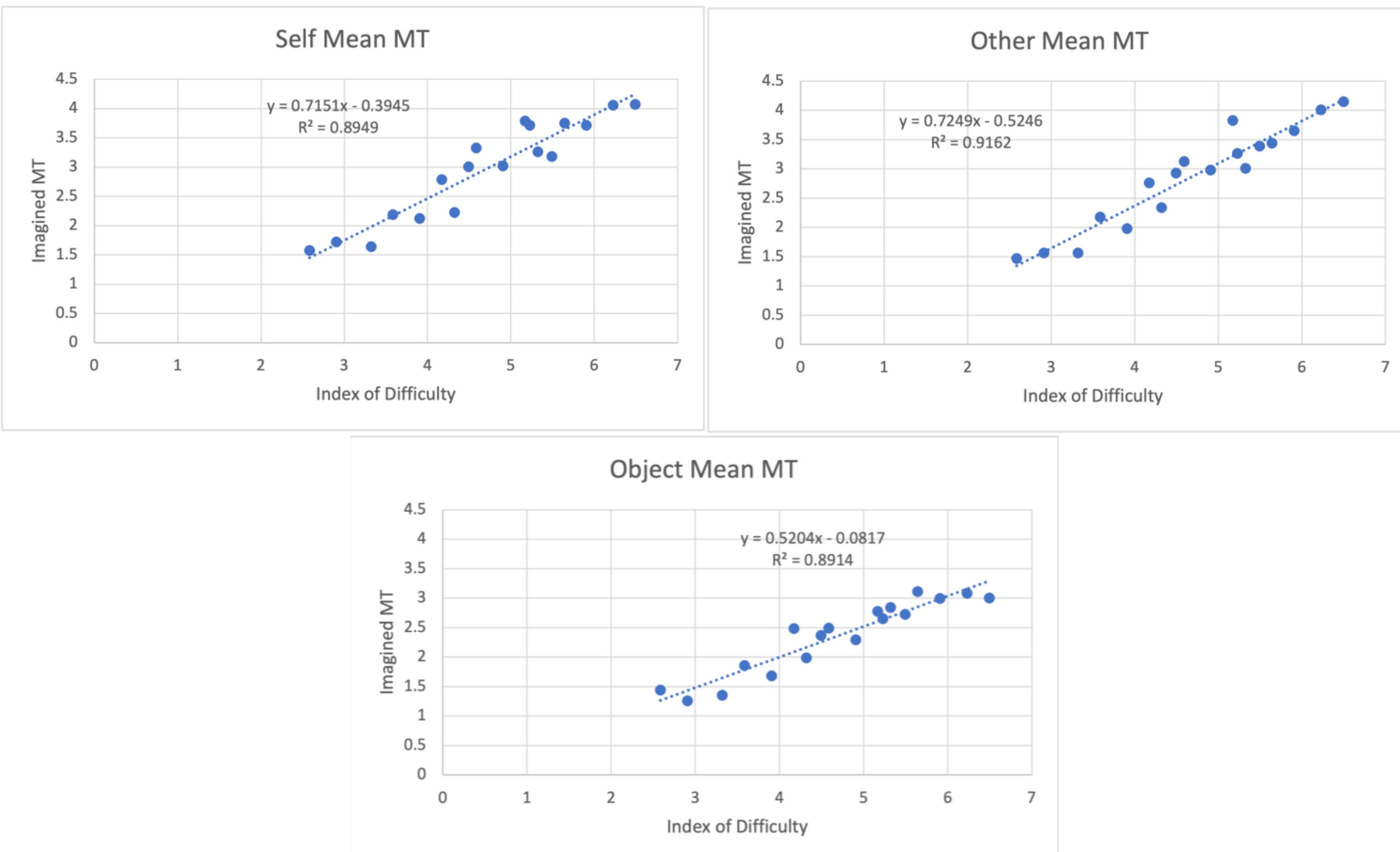
Participants completed the entirety of this study online. They were asked to perform this study on a computer, rather than a phone or tablet, and to complete it in one sitting within 90 minutes. They were provided an informed consent explaining the study before proceeding. Participants filled out the demographics survey and then proceeded to the tasks. A practice task explained the procedure, asking them to imagine the movement, regardless of condition, fully and to the target in a straight line "as quickly as possible while remaining accurate." Participants viewed the image, with the X, person, or object at the starting position and a target at a certain distance and width, and were asked to close their eyes and hit the spacebar to begin the trial and again when they imagined the subject of the trial reaching the gate. Conditions were presented in a randomized order. Within conditions, each combination of distance and width was repeated twice, in a randomized order, for a total of 48 trials per condition, 144 trials overall. Following the tasks, participants completed the Godspeed Anthropomorphism sub-scale, the VVIQ, and answered questions about their height, weight, and shoulder width. They were also asked to report whether they completed the study truthfully after being assured that their credit would not be affected, as well as to briefly summarize their imagery strategy.

Results

Of 32 participants who finished the experiment, 3 were removed for answering yes to the honesty question (see Appendix G), 1 was removed for satisficing behavior (straight-lining all surveys), and 2 were removed for evidence of not following instructions, including multiple trials over a minute (the average trial was under 3 seconds for the remaining 26 participants), followed by some well under half a second, with no discernible pattern of response. 26 participants were thus analyzed, including 10 males (38.46%) and 16 females (61.53%). Ages ranged from 18 to 43 (M = 22.31; SD = 6.85). In addition to the participants excluded, 43 trials across 7 participants were excluded from analysis following an outlier analysis. Of 3744 trials, imagined MT had a mean of 2.92 seconds (SD = 3.13). An outlier cutoff of 3 standard deviations above the mean was calculated (12.32 s) and all trials above that threshold were excluded for a remaining total of 3701 trials across. In addition, participants were inconsistent in their reporting of shoulder width information, and this variable was not used in the analyses. Weight and height data were instead used to calculate body mass index (weight / height^2, weight in kilograms and height in meters; “Body Mass Index, 2020) to test whether body size impacted the perception of gate passability.

Figure 1

Graphs of simple linear regressions for each condition, formula and r^2 *provided*



Simple linear regressions were performed for all three conditions averaging across participants. The self-imagery condition had an r^2 of .90 ($F(1, 16) = 136.28$, $p < .001$), the other-imagery condition had an r^2 of .92 ($F(1, 16) = 174.92$, $p < .001$), and the object-imagery condition had an r^2 of .89 ($F(1, 16) = 131.38$, $p < .001$) (see all three conditions in Figure 1).

Logistic regressions were performed on the overall mean MT values to compare slopes and intercepts between conditions two at a time. In each logistic regression, ID, Condition, and an interaction term were entered as predictors. The first regression compared the object-imagery and other-imagery conditions. The model was significant, $F(3, 35) = 184.92$, $p < .001$, $r^2 = .95$. ID was a significant predictor ($\beta = .68$, $t = 12.18$, $p < .001$). Condition was significant, indicating an intercept difference between conditions ($\beta = -.40$, $t = -2.78$, $p = .009$). The interaction term was also significant, indicating a slope difference between conditions ($\beta = .79$, $t = 5.34$, $p < .001$).

The second logistic regression compared other-imagery and self-imagery. The model was significant ($F(3, 32) = 114.24$, $p < .001$, $r^2 = .92$). ID was a significant predictor ($\beta = .87$, $t = 12.46$, $p < .001$). Condition was not significant, indicating no significant intercept difference ($\beta = -.27$, $t = -1.47$, $p = .152$). The interaction term was not significant either, indicating no significant difference in slope between conditions ($\beta = .34$, $t = 1.82$, $p = .078$).

The final logistic regression compared self-imagery and object-imagery. The model was significant, $F(3, 32) = 175.69$, $p < .000$, $r^2 = .94$. ID was a significant predictor ($\beta = .66$, $t = 11.56$, $p < .001$). Condition was significant, indicating an intercept difference between conditions ($\beta = -.39$, $t = -2.62$, $p = .013$). The interaction term was also significant, indicating a difference in slope ($\beta = .84$, $t = 5.39$, $p < .001$).

To examine whether VVIQ, Godspeed, or BMI were predictive of performance, the Index of Performance (IP; calculated as the inverse of the slope; Fitts, 1954) was calculated for each participant and each condition, and then correlated with VVIQ, Godspeed, and BMI. VVIQ scores ($N = 26$, $M = 59.27$, $SD = 12.90$; scale from 16-80 with higher scores indicating clearer mental imagery) were not significantly correlated to object IP ($r = .04$, $p = .86$), other IP (r = -

.19, p = .36), nor self IP (r = -.01, p = .95). Godspeed scores (N = 26, M = 11.77, SD = 4.53; scale of 5-25 with higher scores indicating higher levels of anthropomorphism) were not significantly correlated to object IP (r = .31, p = .13), other IP (r = .22, p = .29), nor self IP (r = -.37, p = .06). BMI scores (N = 26, M = 24.36, SD = 4.10) were not significantly correlated to object IP (r = -.02, p = .93), other IP (r = .01, p = .98), nor self IP (r = .33, p = .10).

Discussion

Consistent with the hypothesis and Bakker et al. (2007), self-motor imagery did follow Fitts' law as evidenced by an r^2 value of .90 in the self-imagery condition. Further, the hypothesis that perception of others mirrors perception of self-motion was supported by an r^2 of .92 in the other-imagery condition. However, the prediction that object-imagery would not follow Fitts' law was not supported, as the condition had a similar r^2 of .89. These results seem to imply that either the distinction between VI and MI is not warranted, or that imagining the disc move in this experiment, in opposition to the results of Bakker et al. (2007), did in fact activate motor imagery in a similar manner as imagining oneself or another person moving. However, further analysis does shed light on differences between object-imagery and the other two conditions. Logistic regressions, as well as a glance at figure 1, showed that the conditions produced significantly different functions in both slope and intercept in their linear regressions. Object-imagery was shown to be different from both self and other-imagery, but self and other-imagery were not significantly different. In addition, taking a look at the MTs at an ID of 5 in figure 1 will illustrate that the object conditions slope causes the MTs to be lower at higher IDs, implying that participants imagined the disc to be moving faster and with more accuracy than either themselves or the other agent. An important piece of context for this distinction of object-imagery is the IP, discussed earlier as the inverse of the slope. Conceptually it is thought of as bandwidth, with units of bits per second, and represents an upper limit on how much information can be processed by the person performing the action in question (MacKenzie, 1992). In physical Fitts' tasks such as pointing or walking there is a definitive and biological limit to the speed and accuracy with which the task can possibly be completed successfully. That is, at a certain point, no matter the person or training involved, it is not possible to point to that size target at that distance any faster without making a mistake. Thus, bandwidth reflects a real constraint on motor performance. However, in the virtual task performed in this study, there is no definitive limit. Participants, in essence, set their own limit by estimating "how fast can I/they/this object get there without missing the gates?" It is unclear on what basis participants selected a bandwidth limit to self, other, and object, but this distinction offers an intriguing result: on average, participants assigned a higher bandwidth to the object than to themselves or the other. They still constrained the object's movement abilities according to Fitts' law, but the object had a significantly higher IP.

Effects of the Subject of MI

What is the cause of this difference in attributed IP? Since self and other were similar, it could be biological motion, or specifically human motion, that results in their similarity and their distinctness from object-imagery. Future studies should attempt to identify what traits of the subject impact MI, perhaps testing human motion vs other biological motion (dogs, birds, etc.) to determine whether it is any biological or specifically human motion which results in the same patterns of MI as self-imagery. In the current study, participants did not see the avatar representing the humanoid agent move, and thus had no information about its dynamic properties. In addition, various attributes of objects should be tested to see if they impact MI differently than the disc in Bakker et al. (2007) or this study did. Shape, color, and perceived passability (in reference to the gate width) are just a few of the potential variables that could be tested in future research. Further, we note the spatial scale of the virtual environment may have been ambiguous. The 3D environment was displayed on a 2D screen, and given that the experiment was conducted remotely, we lacked control of screen size and resolution, both of which can affect perception of size and distance (Creem-Regehr et al., 2005; DeLucia, 1991).

Implications

As discussed earlier, MI has multiple practical applications, including injury rehabilitation, athletic training, and other clinical uses (Guillot & Collet, 2008; Lebon et al., 2012; Moukarzel et al., 2019; Nicholson et al., 2018; Saimpont et al., 2013). The implications of this study, that MI of others appears to function nearly indistinguishably from self-imagery, open up the possibility that imagining others move could have some of the same effects and uses as MI practices focused on the self currently do. It is possible that in some contexts, or for some people, that it could be more convenient to make someone else the subject of MI and still be able to unlock its benefits.

Additionally, this finding is of theoretical interest. It is not fully known why or how imagined movement displays such a layered connection with real movement. Our findings point to the need for further studies refining how, when, and in what way MI changes based on the subject (self, other, objects), subject characteristics (size, biology, color), task (pointing, stretching, walking, etc.) and context (being in the physical space, in VR, viewing 2D images). For example, it has been shown that distance judgments expressed via a blind-walking task can be recalibrated based on perturbed optic flow (Rieser et al., 1995). Can this recalibrated walking carryover into motor imagery?

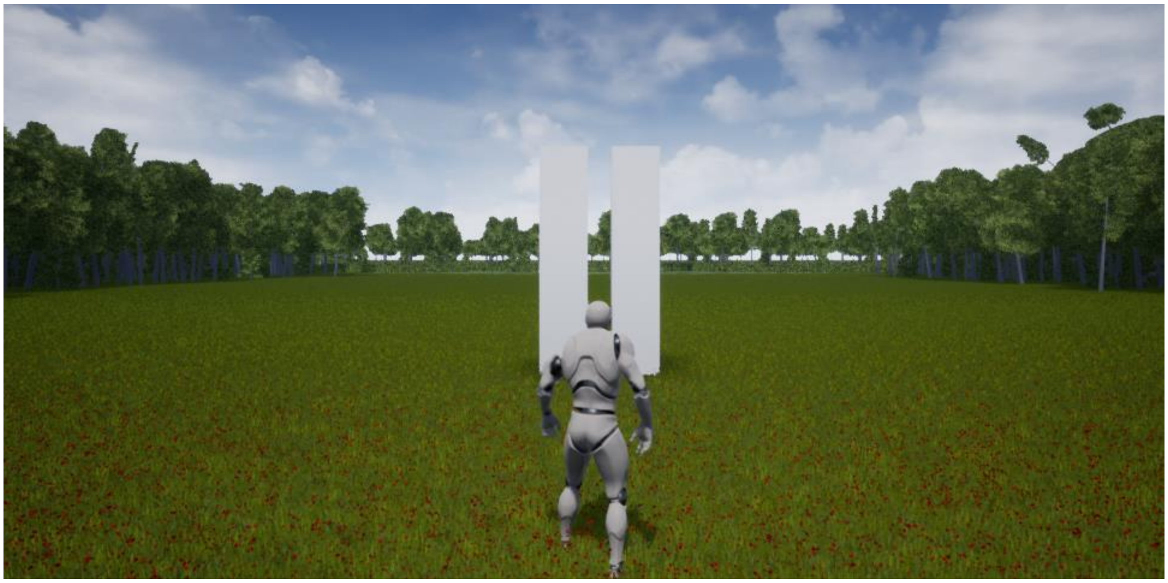
Limitations

Some of the limitations of this study include an uncontrolled viewing of the images presented for the MI tasks. Due to the online nature of the study, the resolution, window size, clarity, and other factors of the viewing could not be controlled amongst participants. Future research could control for this by performing a similar study in a controlled environment, or by presenting images in stereoscopic VR. Another impact of performing this study online is that instructions were only provided through text, and it was clear that some of the participants who had to be excluded did not thoroughly read them or were not able to understand them completely. In future online studies, perhaps a video medium of instruction would be more engaging, and in-person studies have the implicit benefit of capturing attention more thoroughly. Additionally, to most effectively analyze the impacts of this research on patient populations going through injury rehabilitation or in older adults, those populations need to be included in future studies.

Conclusions

This study set out to examine the differences between self, other, and object as the subjects of a MI task utilizing 2D images of a virtual environment. The results suggest, in contrast to Bakker et al. (2007), that imagery of an object does follow Fitts' law in activating motor imagery. However, the evidence indicates that there is a quantitative but not qualitative difference between object and the other two conditions. A possible explanation of this difference is an assignment of different IPs, or bandwidths, based on the subject of MI. Further studies should explore this possibility and if the assigned IP can be manipulated, as well as if it has an impact on some of the practical uses of MI.

APPENDIX A: VIRTUAL ENVIRONMENT



APPENDIX B: HUMANOID AGENT

APPENDIX C: GODSPEED SERIES QUESTIONNAIRE

Appendix

GODSPEED I: ANTHROPOMORPHISM

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

Fake 偽物のような	1	2	3	4	5	Natural 自然な
Machinelike 機械的	1	2	3	4	5	Humanlike 人間的
Unconscious 意識を持たない	1	2	3	4	5	Conscious 意識を持っている
Artificial 人工的	1	2	3	4	5	Lifelike 生物的
Moving rigidly ぎこちない動き	1	2	3	4	5	Moving elegantly洗練された動き

GODSPEED II: ANIMACY

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

Dead 死んでいる	1	2	3	4	5	Alive 生きている
Stagnant 活気のない	1	2	3	4	5	Lively 生き生きとした
Mechanical 機械的な	1	2	3	4	5	Organic 有機的な
Artificial 人工的な	1	2	3	4	5	Lifelike 生物的な
Inert 不活発な	1	2	3	4	5	Interactive 対話的な
Apathetic 無関心な	1	2	3	4	5	Responsive 反応のある

GODSPEED III: LIKEABILITY

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

Dislike 嫌い	1	2	3	4	5	Like 好き
Unfriendly 親しみにくい	1	2	3	4	5	Friendly 親しみやすい
Unkind 不親切な	1	2	3	4	5	Kind 親切な
Unpleasant 不愉快な	1	2	3	4	5	Pleasant 愉快な
Awful ひどい	1	2	3	4	5	Nice 良い

GODSPEED IV: PERCEIVED INTELLIGENCE

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

Incompetent 無能な	1	2	3	4	5	Competent 有能な
Ignorant 無知な	1	2	3	4	5	Knowledgeable 物知りな
Irresponsible 無責任な	1	2	3	4	5	Responsible 責任のある
Unintelligent 知的でない,	1	2	3	4	5	Intelligent 知的な
Foolish 愚かな	1	2	3	4	5	Sensible 賢明な

GODSPEED V: PERCEIVED SAFETY

Please rate your emotional state on these scales:

以下のスケールに基づいてあなたの心の状態を評価してください。

Anxious 不安な	1	2	3	4	5	Relaxed 落ち着いた
Agitated 動揺している	1	2	3	4	5	Calm 冷静な
Quiescent 平穏な	1	2	3	4	5	Surprised 驚いた

APPENDIX D: VIVIDNESS OF VISUAL IMAGERY QUESTIONNAIRE

Vividness of Visual Imagery Questionnaire (VVIQ)

For each item on this questionnaire, try to form a visual image in your mind and consider your experience carefully.

For any image that you do experience, rate how vivid that image appears in your mind by using the five-point scale below. If you do not have a visual image, rate vividness as ‘1’. Only use ‘5’ for images that are truly as lively and vivid as seeing that object in front of you. Please note that there are no right or wrong answers to the questions, and that it is not necessarily desirable to experience imagery or, if you do, to have more vivid imagery.

(5) - Perfectly clear and vivid as real seeing
(4) - Clear and reasonably vivid
(3) - Moderately clear and lively
(2) - Vague and dim
(1) - No image at all, you only “know” that you are thinking of the object

For items 1-4, think of some relative or friend whom you frequently see (but who is not with you at present). Consider carefully the picture that comes before your mind’s eye.

1. The exact contour of face, head, shoulders and body. ________________
2. Characteristic poses of head, attitudes of body etc. ________________
3. The precise movement, length of step etc., in walking. ________________
4. The different colours worn in some familiar clothes. ------------________________

For items 5-8, visualise a rising sun.
Consider carefully the picture that comes before your mind’s eye.

5. The sun rising above the horizon into a hazy sky. ________________
6. The sky clears and surrounds the sun with blueness. ________________
7. Clouds. A storm blows up with flashes of lightning. ________________
8. A rainbow appears. ________________

For items 9-12, think of the front of a shop which you often go to.
Consider the picture that comes before your mind’s eye.

9. The overall appearance of the shop from the opposite side of the road ________________

10. A window display including colours, shapes and details of individual items for sale. ________________

11. You are near the entrance. The colour, shape and

details of the door. ________________

12. You enter the shop and go to the counter. The counter assistant serves you. Money changes hands. ________________

For items 13-16, think of a country scene which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye.

13. The contours of the landscape. ________________
14. The colour and shape of the trees. ________________
15. The colour and shape of the lake. ________________
16. A strong wind blows on the trees and on the lake causing waves in the water. ________________

APPENDIX E: IRB APPROVAL LETTER

UNIVERSITY OF CENTRAL FLORIDA

Institutional Review Board
FWA00000351
IRB00001138, IRB00012110
Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

EXEMPTION DETERMINATION

January 11, 2021

Dear Daniel Mcconnell:

On 1/11/2021, the IRB determined the following submission to be human subjects research that is exempt from regulation:

Type of Review:	Initial Study, Initial Study
Title:	Utilizing Fitts' Law to Examine Motor Imagery of Self, Other, and Objects
Investigator:	Daniel Mcconnell
IRB ID:	STUDY00002601
Funding:	None
Grant ID:	None
Documents Reviewed:	• Demographics.pdf, Category: Survey / Questionnaire; • Godspeed anthropomorphism subscale.pdf, Category: Survey / Questionnaire; • HRP-254-FORM Explanation of Research.pdf, Category: Consent Form; • HRP-255-FORM - Request for Exemption.docx, Category: IRB Protocol; • Object-imagery example 2.pdf, Category: Other; • Object-imagery example 3.pdf, Category: Other; • Object-imagery example.pdf, Category: Other; • Other-imagery example 2.pdf, Category: Other; • Other-imagery example 3.pdf, Category: Other; • Other-imagery example.pdf, Category: Other; • Self-imagery example 2.pdf, Category: Other; • Self-imagery example 3.pdf, Category: Other; • Self-imagery example.pdf, Category: Other; • Self-report questions.pdf, Category: Survey / Questionnaire; • Vividness of Visual Imagery Questionnaire.pdf, Category: Survey / Questionnaire

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made, and there are questions about whether these changes affect the exempt status of the human research, please submit a modification request to the IRB. Guidance on submitting Modifications and Administrative Check-in are detailed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Katie Kilgore

Katie Kilgore
Designated Reviewer

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APPENDIX F: DEMOGRAPHICS

Demographics Questions

1. What is your age? __________
2. Specify your gender:
    a. Female
    b. Male
    c. Nonbinary
    d. Other, please specify ______
    e. Prefer not to say
3. What is your major?

APPENDIX G: SELF-REPORT QUESTIONS

Self-Report Questions

1.) What is your height (In feet and inches)? ______

2.) What is your weight (in pounds)? ______

3.) What is your approximate shoulder width in inches (if you can, use a tape measure or other device and measure, from the front, between the end of each shoulder bone, or humerus, with shoulders relaxed)? ______

If you cannot use a tape measure, please estimate your shoulder width:

a. Narrow
b. Average
c. Wide

4.) Please briefly describe your strategy for imagining movement during the tasks:

____

5.) In research, unwilling participants often click through surveys without reading or considering the question/item. Unfortunately, this can pose a problem with the quality of the study results and the reputation of UCF.

Did you at any point in this survey answer the questions by clicking through randomly or not being truthful in your answers? (If you answer yes, you will still get your SONA points and you will not get in any trouble. This allows us to exclude your results once we look at the data and improve the quality of the research. Thank you for your honesty!).

a. Yes
b. No

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