Running Header: ACTION MEASURE SHOWS ACTION-SPECIFIC EFFECT ON PERCEPTION

In Absence of an Explicit Judgment, Action-specific Effects Still Influence an Action Measure of Perceived Speed

Jessica K. Witt

Colorado State University

Action-specific effects, such as a fish appearing faster when it is harder to catch, have been primarily demonstrated using explicit perceptual judgments. These sorts of judgments rely on the cognitive or "what" visual pathway. An open question is whether action-specific effects also influence the action pathway. If fish look faster when the net is small, the net should be released earlier than when the net is big. Previously, this action measure was always paired with an explicit measure of fish speed, which is known to evoke the cognitive visual pathway. Here, net release time was examined without any explicit judgments. The action-specific effect of net size still emerged. Assuming net release time taps into the action pathway, the current studies provide support that action-specific effects occur within both the cognitive and action pathways, possibly because these effects operate on early visual processes prior to the split between the two pathways.

Keywords: Action-perception relationships; action-specific perception; two visual streams

1. Introduction

Conscious spatial perception can be influenced by a person's ability to act. For example, softballs are judged as bigger by batters who are hitting better than others (Gray, 2013; Witt & Proffitt, 2005). These effects are known as action-specific effects on perception (Witt, 2011, in press). To date, most studies on action-specific perception have used a conscious measure of perception such as verbal reports or visual matching tasks. Perception, however, encompasses more than just conscious perception. Some researchers have proposed two parallel processing streams, one that gives rise to conscious perception and one that provides information to help guide action. The distinctions between the two pathways have been labeled in many ways, including cognitive and motor (Bridgeman, Lewis, Heit, & Nagle, 1979), cognitive and sensorimotor (Paillard, 1987), what and where (Ungerleider & Mishkin, 1982), and what and how (Milner & Goodale, 1995).

The strongest support for the theory of two visual pathways comes from studies that revealed a dissociation between responses that are thought to tap into the separate pathways. In an early study on neurologically intact humans, Bruce Bridgeman and colleagues had participants make saccadic eye movements back and forth between the left and right sides of a display (Bridgeman et al., 1979). A target was present and sometimes was displaced 2 degrees laterally. Participants were instructed to indicate via button press when they detected this displacement. In addition, they were instructed to point to the target from time to time as triggered by the experimenter. When the displacement occurred within 100 ms of the participants' saccadic eye movement, the displacement was rarely noticed, due to saccadic suppression, whereas the displacement was almost always noticed when it did not coincide with an eye movement. Strikingly, pointing movements were just as accurate regardless of whether the displacement had been noticed or not. This dissociation between errors in conscious detection of displacements versus accurate pointing movements suggests different underlying visual information drives conscious versus motor responses (see also Bridgeman, Kirch, & Sperling, 1981).

The result of this experiment was consistent with the idea that one pathway is for conscious perception, and is the pathway used to make responses related to pressing a button when the displacement was detected, and another pathway for action was used to direct pointing movements. Similar dissociations have been found in other scenarios. For example, visual illusions fool the conscious system, but several studies have shown that actions towards the objects are accurate. In one study, Bridgeman used the visual illusion known as the induced Roelofs effect (Bridgeman, 1991). For this illusion, an object is surrounded by a frame that is positioned to one side of the observer's midline. This positioning leads to the perception of the object's position as being to the side opposite of the frame's offset when the response is a cognitive judgment, such as a verbal report of the object's position. However, when tasked with pointing to the object, movements are accurate and unbiased by the position of the frame (see also Bridgeman, Gemmer, Forsman, & Huemer, 2000; Bridgeman, Peery, & Anand, 1997). Thus, the illusion also reveals a dissociation between cognitive and action measures.

Whether a particular visual illusion affects only cognitive measures versus both cognitive and action measures is theorized to provide insight into the neural mechanism of the illusion. Specifically, illusions that impact early visual areas such as processes in the occipital lobe should produce effects in both cognitive and action measures, whereas illusions that affect late visual areas such as processes in the temporal lobe should affect cognitive but not action measures (Dyde & Milner, 2002). This distinction can be used to investigate the neural mechanisms that drive a particular effect. Here, this distinction was used to address the neural mechanism underlying action-specific effects. If action-specific effects only influence cognitive measures, this suggests later visual (or perhaps even post-visual) processing. If action-specific effects influence both cognitive and action measures, this suggests the effect operates on earlier visual processes.

A prior study that a colleague and I conducted is relevant, although we neglected to discuss the distinction between cognitive and action measures (Witt & Sugovic, 2013). In the study, a fish moved from left to right across a computer display, and participants were given a net to catch the fish. The net was positioned at the bottom right of the display. When participants pressed the mouse, the net was released and moved straight up the display. The participants' task was to release the net at the exact moment necessary to catch the fish with the net. The difficulty of the task was manipulated by rendering the net as small, medium, or big on each trial. After each attempt to catch the fish, participants rated the speed of the fish on a scale from 1 to 7. When the net was big, more fish were successfully caught and participants rated the fish as slower compared with when the net was small. Thus, the explicit measure of perceived speed revealed an action-specific effect. What was noteworthy in this study was that an action measure was also obtained. Specifically, the time at which the net was released provided an action measure of perceived speed: if the fish appeared slower when the net was big, participants should wait longer to release the big net. This is what the data showed. Follow-up studies ruled out a strategy-based explanation. The center of the nets were aligned at the beginning of each trial, so participants could have waited longer to release the big net if they had been trying to catch the fish with the top of the net rather than the middle because the top of the big net did not have to travel as far as the top of the small net. However, this was not the strategy participants used, favoring instead to try to catch the fish with the center of the net to maximize room for error (see also Trommershauser, Maloney, & Landy, 2003). That both explicit judgments and action measures showed the action-specific effect of net height on perceived speed suggests the neural mechanism for action-specific effects is early in visual processing.

Another possibility, however, is that the task of having to make an explicit speed judgment altered the relative contributions of processing from the two pathways. In prior work, Bridgeman and colleagues found that pointing responses were influenced by the induced Roelofs effect if an explicit judgment was also made on each trial, whereas they were not influenced when an explicit judgment was not made (Bridgeman et al., 1997). The task of having to explicitly judge location resulted in pointing movements being influenced in the same way as explicit judgments, which was interpreted as both relying on information from the same processing stream or map. Interactions in the opposite direction have also been found: having to make an action response altered the cognitive judgment (Vishton et al., 2007). Participants selected which of two circles was larger. When the circles were embedded in an Ebbinghaus illusion, the one surrounded by larger circles appeared smaller than the circle surrounded by smaller circles. However, the magnitude of the influence of the surrounding circles diminished when participants had to select and grasp the larger circle, rather than just select it without grasping. This suggests a dynamic interaction between the two pathways such that involvement of one diminished the involvement of the other. If a similar dynamic applies to the action-specific perception effect found in the fishing task, action might be influenced by changes in task difficulty when an explicit judgment is also made but action might not be influenced in the absence of any explicit judgments. This possibility was tested here.

2. Experiment 1: Explicit Judgments and Action-based Measures

Participants attempted to block a fish moving across a computer screen by pressing the mouse to release a net. Task difficulty was manipulating by altering the height of the net on each trial. After each attempt, participants explicitly estimated the speed of the fish. In addition, the time at which they released the net also served as a measure of perceived fish speed. If the fish appeared faster when the net was small, participants should release the small net sooner than releasing the big net. This study replicated prior work for which both an explicit judgment and an action measure were made, and also provides a control condition for Experiment 2, for which only the action measure was made.

2.1 Method

2.1.1 Participants. Thirteen students taking Introductory Psychology participanted in exchange for course credit.

2.1.2 Stimuli and Apparatus. Stimuli were presented on a 51 x 29 cm monitor with 1920 x 1080 resolution.

2.1.3 Procedure. Participants were initially trained on the slow and fast anchor speeds. The slow speed (3.2 cm/s) and fast speed (12.8 cm/s) were shown two times each, and order was randomized. For each presentation, text on the screen indicated whether the speed was slow or fast prior to the fish moving across the screen. For the second part of training, the anchor speeds were again shown twice each, but this time instead of text indicating the speed, the participant had to judge whether the speed was fast or slow. They made their response on a mouse. The left mouse button corresponded to slow and the right mouse button corresponded to fast.

On each test trial, the fish was 2.3 cm wide and 2 cm tall. The fish's initial position was 14 cm from the left side of the screen and was positioned high or low (5.3 or 8.0 cm from the top of the display, respectively). The net started 14 cm from the right side of the screen. On each trial, the net was 0.7 cm wide and set to be 1 of 3 heights (1.3, 4.0, or 8.0 cm). The initial vertical position of the net was set so that the center of the net was in the same place on every trial. Given that participants attempt to catch fish at the center of the net (see Witt & Sugovic, 2013), this equates the position of the nets relative to this strategy. Figure 1 shows the start of a trial with the small net and the high fish.

At the start of each trial, the fish immediately began to move across the screen at 1 of 6 speeds ranging from (3.2 – 11.2 cm/s). Participants released the net in an attempt to catch the fish. To release the net, participants pressed the left button on the mouse, at which point, the net moved up at a constant speed of 3.2 cm/s. If the net was positioned so that its left edge blocked the path of the fish, the fish stopped on the net; otherwise the fish moved beyond the net while the net continued to move up the screen. After each attempt, regardless of whether it was successful or not, participants estimated whether the fish moved more like the slow speed or more like the fast speed. They made their response by pressing the corresponding button on the mouse. They were given as long as needed to make their speed judgment, and they received no feedback about their speed judgments. After each judgment, a screen with the word "next" was presented for 1000 ms before the next trial began. Participants completed 8 blocks of trials. Each block contained 36 trials with all combinations of net height (small, medium, big), initial fish position (high, low), and fish speed. Order within block was randomized.

Figure 1. Screenshot of the start of a trial with the high fish and the small net. Factors that were manipulated included the position of the fish (high, as shown here, or low) and the height of the net (small, as shown here, medium, or big). The nets were positioned so that the center of each net was always in the same location.

2.1.4 Data Analysis. All data were analyzed in R (R Core Team, 2017). Within-subject and mixed ANOVAs were analyzed using the aov_car function in the afex package (Singmann, Bolker, Westfall, & Aust, 2017)**.** This analysis provides Greenhouse-Geisser corrected degrees of freedom to account for possible violations of sphericity, which is why the degrees of freedom are not always integers.

2.2 Results and Discussion

Because one of the main dependent measures was net release time (netRT), the data were initially processed to exclude outliers related to netRTs. NetRTs were plotted as a function of fish speed in a boxplot, and any data points greater than 1.5 times the interquartile range were excluded from the data set. This resulted in the exclusion of 2% of the data.

As a manipulation check, proportion of fish successfully blocked were submitted to a within-subjects ANOVA with fish speed, fish position, and net height as within-subjects factors. All main effects and interactions were significant, *p*s < .001, η_p^2s > .40 (see Figure 2).

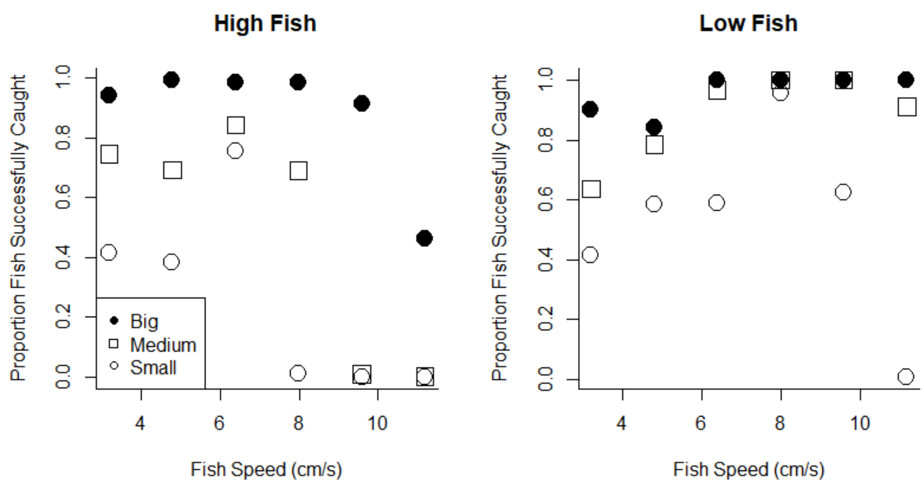

Figure 2. Mean proportion of fish successfully blocked as a function of fish position, fish speed, and net height for Experiment 1.

Next, explicit judgments were analyzed. With a speed-bisection task like the one used here, the data are summarized by calculating the point of subjective equality (PSE) for each subject for each net height and fish position combination. PSEs were calculated from the slopes and intercepts of binary logistic regressions for each combination. A lower PSE indicates that the fish were judged as faster. PSEs were submitted to a repeated-measures ANOVA with net height and fish position as within-subjects factors. Net height significantly influenced PSEs, $F(1.99, 23.89) = 9.25$, $p = .001$, $\eta_p^2 = .44$ (see Figure 3). Fish position did not influence PSEs, $F(1,12) = 1.24$, $p = .29$, $\eta_p^2 = .09$. The interaction was not significant, $F(1.80, 21.60) = 1.82$, $p = .19$, $\eta_p^2 = .13$. The results show that fish were judged to move faster when the net was small than when it was big.

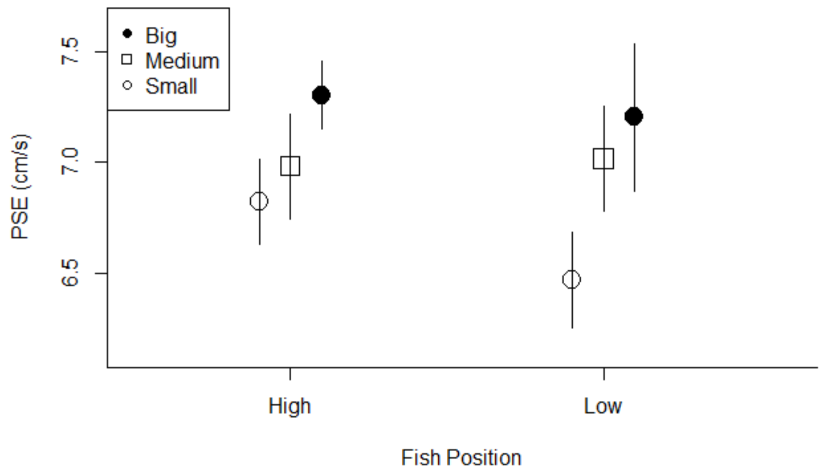

Figure 3. Mean PSEs as a function of fish position and net height for Experiment 1. A lower PSE indicates the fish was judged as moving faster. Error bars are 95% confidence intervals calculated within-subjects.

The results replicate previous studies using this task. In the original version, participants estimated the speed of the fish on a scale of 1 to 7 (Witt & Sugovic, 2013). In another version, participants used this speed bisection task while also performing a secondary task that forced participants to attend to the fish or, in another experiment, to the center of the display (Witt, Sugovic, & Dodd, 2016). The current results replicate the previous findings that explicit judgments are influenced by the height of the net.

Next, netRTs were submitted to a repeated-measures ANOVA with net height, fish speed, and fish position as within-subjects factors. Fish speed significantly influenced netRTs, $F(1.34, 16.13) = 216.65$, $p < .001$, $\eta_p^2 = .95$. Participants released the net sooner when the fish was faster. Fish position significantly influenced netRTs, $F(1, 12) = 95.92$, $p < .001$, $\eta_p^2 = .89$. Participants released the net sooner when the fish was higher than when it was lower. The interaction between fish speed and fish position was significant, $F(2.13, 25.62) = 18.13$, $p < .001$, $\eta_p^2 = .60$. Critically, net height influenced netRTs, $F(1.99, 23.91) = 12.37$, $p < .001$, $\eta_p^2 = .51$ (see Figures 4 and 5). Participants released the small net earlier than the big net. This is consistent with the claim that the fish looks faster when the net is small than when it is big. This also replicates previous findings for which net height influenced netRTs when an explicit judgment was also made (Witt & Sugovic, 2013). The interaction between net height and fish speed was not significant, $F(3.98, 47.82) = 1.92$, $p = .12$, $\eta_p^2 = .14$. The interaction between net height and fish position was not significant, $F(1.95, 23.37) = 0.45$, $p = .64$, $\eta_p^2 = .04$. The 3-way interaction between net height, fish position, and fish speed was not significant, $F(2.66, 31.94) = 2.19$, $p = .11$, $\eta_p^2 = .15$.

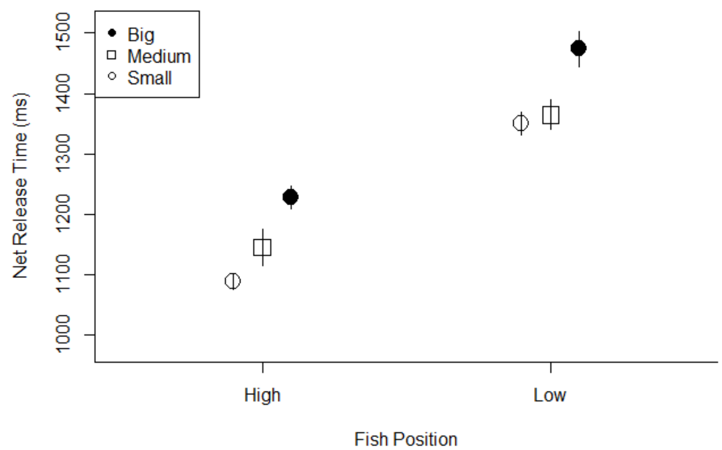

Figure 4. Mean net release times as a function of fish position and net height for Experiment 1. A higher net release time indicates participants waited longer to release the net, as would be found if the fish were perceived as slower. Error bars are 95% confidence intervals calculated within-subjects.

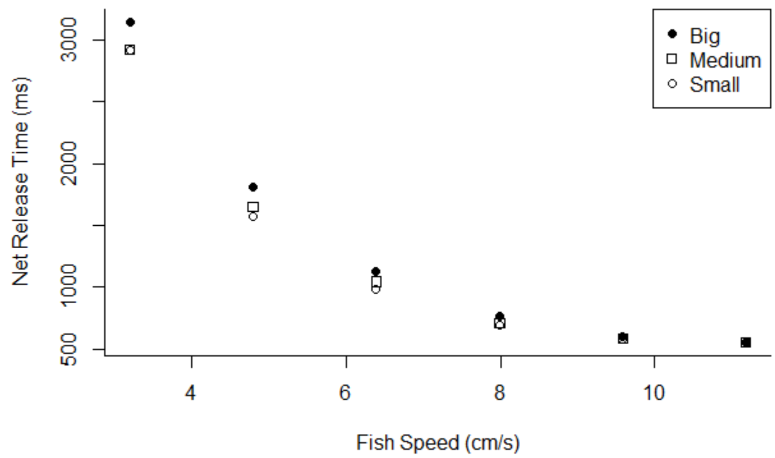

Figure 5. Mean net release times as a function of fish speed and net height for Experiment 1. A higher net release time indicates participants waited longer to release the net, as would be found if the fish were perceived as slower.

The effect of net height on perceived speed can be directly compared across the two types of measures by calculating the fish effect for each measure. The fish effect is calculated as a percentage by subtracting the score (PSE or RT) with the small net from the score with the big net, then dividing by the score with the small net. A paired-sample t-test showed no significant difference between the two measures of the fish effect, $t(12) = 0.92$, $p = .37$ (see Figure 6). Both measures showed the action-specific effect of ease to catch the fish on perceived fish speed.

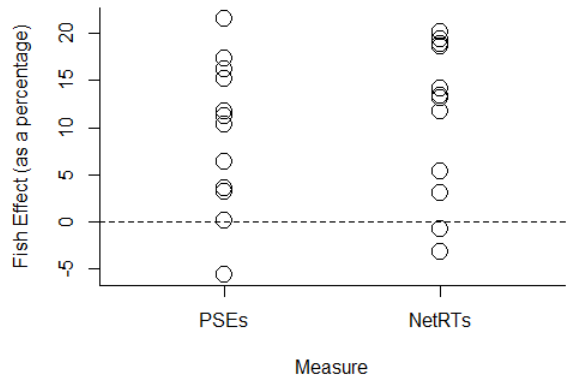

Figure 6. The fish effect shows the magnitude of the effect of the net height on measure of perceived fish speed, calculated for both PSEs and netRTs. A higher score indicates a larger effect of net height on perceived fish speed, and a positive score indicates the fish appeared faster with the smaller net. Each point is for an individual participant, and each participant has one point for each of the two measures.

2. Experiment 2: No Explicit Judgment

It is possible that knowing an explicit judgment was to be made engaged the cognitive processing stream, which then influenced the actions. This explanation was previously applied to the induced Roelefs effect: pointing movements were accurate when no explicit judgment was made but biased when an explicit judgment was also made (Bridgeman et al., 1997). In addition, the reverse of this pattern had been demonstrated previously: the Ebbinghaus illusion influenced explicit judgments but to a lesser extent when a grasp was to be made (Vishton et al., 2007). In Experiment 1 and in previous studies using this fishing task, an explicit judgment was made on every trial. If the task of making an explicit judgment engaged the cognitive processing stream and that drove the action measure of net release time, it is not surprising that net release times were influenced by net height. The critical test, then, is whether net release times would also be affected by net height when no explicit judgment is made of fish speed.

3.1 Method

Fourteen students participated in exchange for course credit for their introductory course. Everything was the same in Experiment 1 except participants did not engage in the initial training on the anchor speeds, and they never made an explicit judgment of fish speed. On each trial, the fish started to move across the screen, and participants released the net to catch the fish. There was a 1000ms break in between trials. Given that the trials were shorter because participants did not have to make a speed judgment, they completed 10 blocks instead of 8 blocks.

3.2 Results and Discussion

NetRTs were examined for outliers and outliers were excluded, as in Experiment 1. Proportion of fish successfully caught was significantly influenced by net height, $F(1.82, 23.67) = 731.74$, $p < .001$, $\eta_p^2 = .98$, confirming that the manipulation of net height significantly impacted fish catching performance. All main effects of and interactions between net height, fish speed, and fish position were significant, *p*s < .001 (see Figure 7).

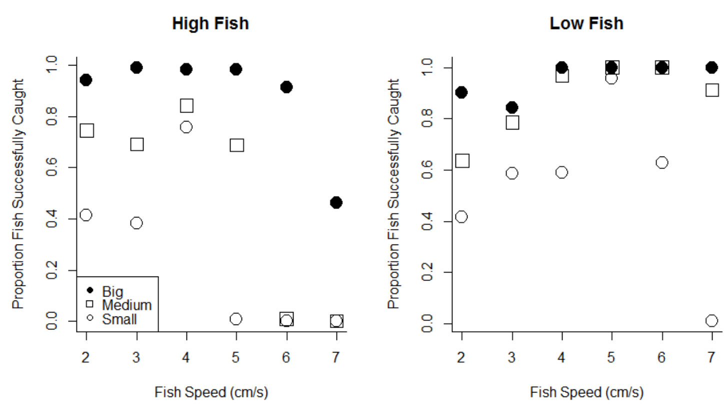

Figure 7. Mean proportion of fish successfully blocked as a function of fish position, fish speed, and net height for Experiment 2.

NetRTs were submitted to a repeated-measures ANOVA with net height, fish speed, and fish position as within-subjects factors. Fish speed influenced netRTs, $F(1.69, 22.03) = 1043.14$, $p < .001$, $\eta_p^2 = .99$. The net was released sooner when the fish was faster. Fish position influenced netRTs, $F(1, 13) = 105.15$, $p < .001$, $\eta_p^2 = .89$. The net was released sooner when the fish was higher. The interaction between fish speed and fish position as significant, $F(2.02, 26.29) = 35.16$, $p < .001$, $\eta_p^2 = .73$. Critically, net height significantly influenced netRTs, $F(1.43, 18.57) = 17.37$, $p < .001$, $\eta_p^2 = .57$. When the net was smaller, participants released it earlier than when the net was bigger (see Figure 8). The interaction between net height and fish speed was significant, $F(3.21, 41.75) = 3.08$, $p = .03$, $\eta_p^2 = .19$. The effect of net height on netRT was bigger for slower fish speeds than for fast fish speeds (see Figure 9). No other interactions were significant, *ps* > .09.

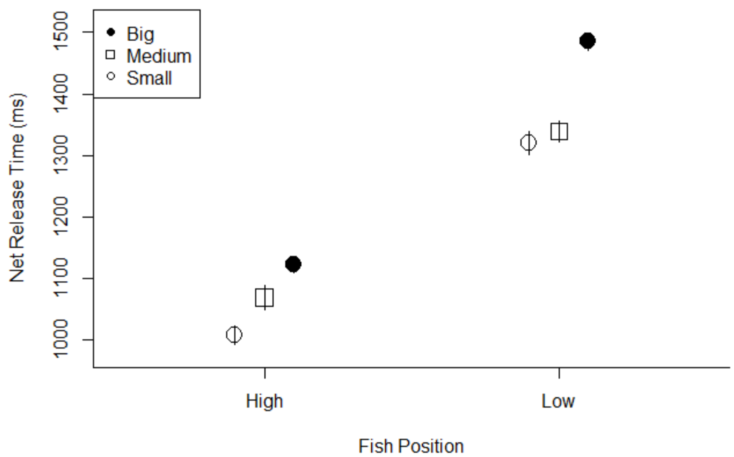

Figure 8. Mean net release times as a function of fish position and net height for Experiment 2. A higher net release time indicates participants waited longer to release the net, as would be found if the fish were perceived as slower. Error bars are 95% confidence intervals calculated within-subjects.

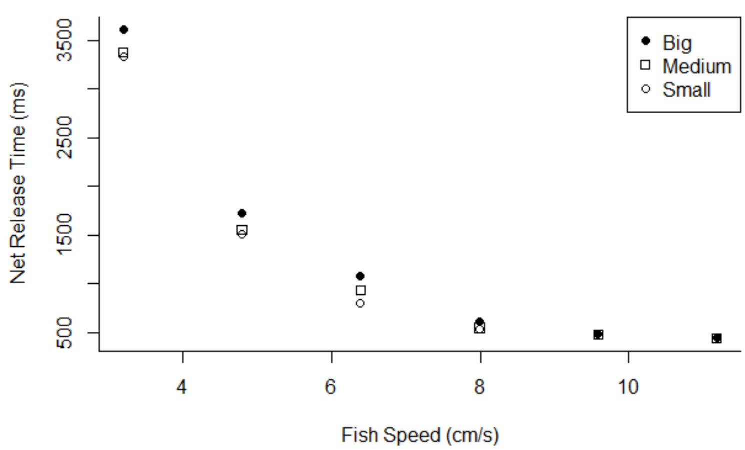

Figure 9. Mean net release times as a function of fish speed and net height for Experiment 2. A higher net release time indicates participants waited longer to release the net, as would be found if the fish were perceived as slower.

Even when an explicit judgment was not made, net height still influenced the action measure of net release time. The data from both experiments were combined to determine whether making an explicit judgment affected the size of the effect of net height on netRT. NetRTs were submitted to a repeated-measures ANOVA with experiment as a between-subjects factor and net height, fish speed, and fish position as within-subjects factors. Net height significantly influenced netRTs, $F(1.81, 45.30) = 29.44$, $p < .001$, $\eta_p^2 = .54$. However, the interaction between experiment and net height was not significant, $F(1.81, 45.30) = 0.20$, $p = .80$, $\eta_p^2 < .01$ (see Figure 10). Thus, making an explicit judgment of fish speed did not impact the action measure of netRT. The interaction between experiment and fish speed was significant, $F(1.46, 36.50) = 10.82$, $p < .001$, $\eta_p^2 = .30$. At the slowest fish speed, participants in Experiment 2 released the net later compared with participants in Experiment 1, whereas this pattern was reversed for all other fish speeds. This switch occurred slightly later when the fish was lower, resulting in a near-significant interaction between experiment, fish speed, and fish position, $F(2.29, 57.24) = 2.52$, $p = .08$, $\eta_p^2 = .09$ (see Figure 11). No other interactions with experiment were significant, *p*s > .37.

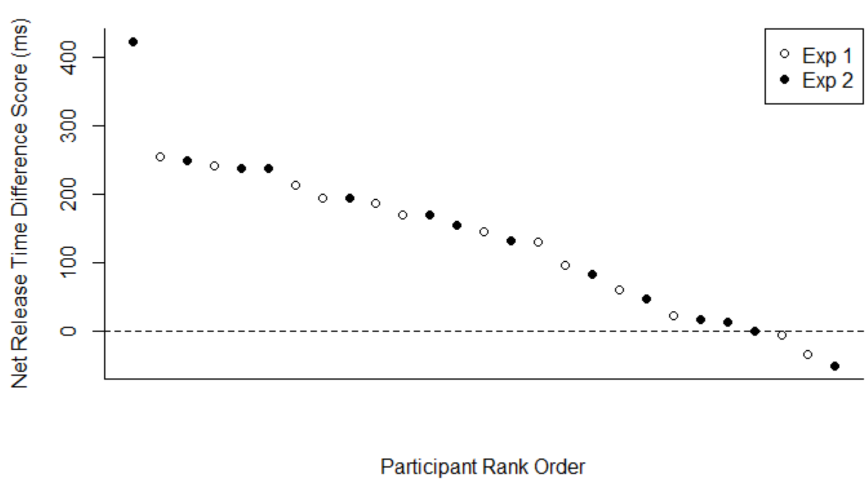

Figure 10. Mean net release time with the big net minus mean net release time with the small net for each participant across both experiments. A positive difference score indicates that participants released the net earlier when the net was small than when it was big. A larger difference score indicates that net height had a larger effect on net release time.

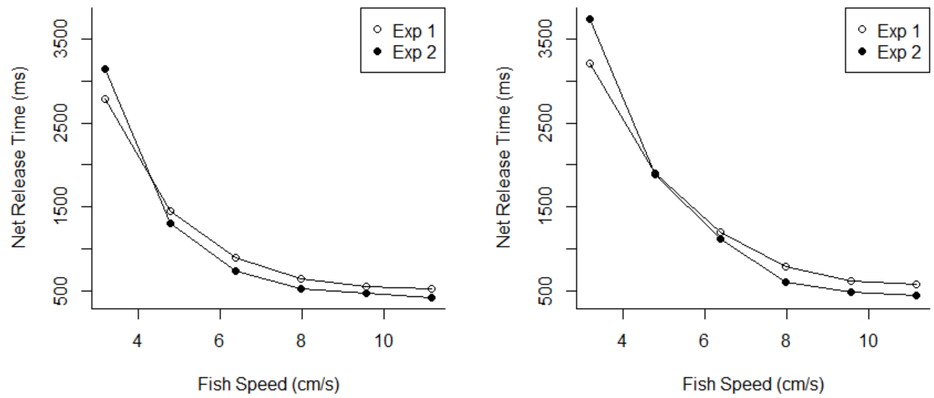

Figure 11. Mean net release times as a function of fish speed, fish position (left panel is for high fish, right panel is for low fish) and experiment.

3. General Discussion

According to the action-specific account of perception, the fish looks faster when it is more difficult to catch, such as when the net is small (Witt & Sugovic, 2013). The current studies explored this action-specific effect using an action measure of perception. The action measure was time to release a net to catch the fish. The results showed that participants released the small net earlier than the big net. This pattern is consistent with the claim that the fish looks faster when the net is small than when it is big.

Prior research revealed that the differences in net release time were not due to differences in strategy across the net heights (Witt & Sugovic, 2013). Specifically, the strategy that could have produced these results is if participants had attempted to catch the fish with the bottom portion of the big net but the top portion of the small net. First, there is no theoretical reason why this strategy would have been adopted. Second, other research has shown that participants tend to aim for the center of targets unless there are penalties associated with movements to one side (Trommershauser et al., 2003; Trommershauser, Maloney, & Landy, 2008). Third, a prior study with the fishing task showed that participants aimed for the middle of each net even when initial positioning of the net could have encouraged an alternative strategy (Witt & Sugovic, 2013). Thus, the effect of net height on net release time seems to be a genuine influence of an action-specific effect on an action measure of perception, rather than due to differences in strategy.

4.1 Cognitive Versus Action Processing Streams

To date, the claims regarding action-specific effects have been primarily concerned with conscious perception. But perception encompasses processes related to both conscious and unconscious perception. According to Bruce Bridgeman and others, one visual pathway is responsible for conscious perception and the other visual pathway is responsible for action-related perception (Bridgeman et al., 1979; Milner & Goodale, 1995; Ungerleider & Mishkin, 1982). Given that the action-specific perception account emphasizes action, it is reasonable to expect these effects to be apparent in action. However, few studies have explored this option.

Some of the initial work on perception of hill slant used a haptic measure (Bhalla & Proffitt, 1999; Proffitt, Bhalla, Gossweiler, & Midgett, 1995). It has been argued that the haptic measure is a form of an action measure (Bhalla & Proffitt, 1999; Proffitt et al., 1995; Witt & Proffitt, 2007). Action-related manipulations such as wearing a backpack or feeling fatigued from a long run influenced verbal and visual measures of conscious perception but not the haptic measure (Bhalla & Proffitt, 1999). It was theorized that the haptic measure tapped into unconscious perception and thus that action-specific effects did not generalize to both pathways of perception. However, later work questioned whether the haptic measure was insensitive to action-related manipulations or rather that physical constraints prevented larger estimates of hill slant regardless of any manipulation (Durgin, Hajnal, Li, Tonge, & Stigliani, 2010). The issue of whether action-specific effects generalized to both pathways was not evaluated further.

In the current studies, the action measure of releasing a net was used to assess perceived speed of a fish in a computer-based task. That the fishing task influenced both conscious and action measures suggests that the locus of the neural mechanism for action's effect on speed perception is early visual areas that feed into both pathways (cf. Dyde & Milner, 2002). Effects that occur in later visual processing stages are considered to effect only measures that tap into that stream. For example, the rod and frame illusion is considered to occur in stages linked to the ventral stream, so it influences cognitive measures of perceived angle but not action-based measures. In contrast, the simultaneous tilt illusion occurs during early visual stages and thus influences both cognitive and action measures of perceived slant. Given that the fishing task produced effects in both the cognitive measure of speed judgments and the action measure of time to release the net, this suggests an earlier locus for action's effects on perceptual processes, according to the Dyde-Milner interpretation (Dyde & Milner, 2002).

The fishing task produced similar effects on action regardless of whether a conscious judgment of ball speed was also made. That the action measure showed similar results regardless of whether a conscious judgment was made is inconsistent with prior work showing communication between the two pathways (Bridgeman et al., 1997; Vishton et al., 2007). However, in the studies on visual illusions, the action measure was immune to the illusion (at least when made in isolation of an explicit judgment), whereas in the fish studies, net release time was influenced by the perceiver's ability to catch the fish both when an explicit judgment was made (as in Experiment 1 and Witt & Sugovic, 2013) and when no explicit speed judgments were made (as in Experiment 2). According to a Dyde-Milner interpretation, this consistent influence on both types of measures suggests the action-specific effect in the fishing task might operate on early visual processing such as those in area MT.

The Dyde-Milner interpretation – that similar effects of action on both verbal and action-based measures suggests that action-specific effects occur early in visual processing – depends on a number of assumptions. One is that the task of releasing the net taps into a different processing stream than the task of judging fish speed. Different processing streams are easier to infer when different measures show a dissociation. Explicit judgments and net release time show convergence, which could be due to action-specific effects operating on early visual processes or could be due to both measures tapping into the same late-vision processing steam.

Just because net release time is an action does not automatically mean it taps into a different processing stream. The division of measures between explicit judgments versus action mapping on to the two different streams has been proven to be too simplistic. Action-based measures can be as susceptible to illusions as verbal measures. As one example, Bridgeman and colleagues found that when the action is performed after a delay during which visual information is no longer available, the action seems to rely on the cognitive stream instead (Bridgeman et al., 1997). The action is still clearly an action, but is considered to no longer be driven by processing the action visual stream. As another example, only actions that are fast and directed to a target are immune to illusions. If the action is directed towards an inferred location, the action is not immune to the induced Roelefs illusion (Dassonville, Bridgeman, Bala, Theim, & Sampanes, 2004).

In the case of releasing the net, the action is performed during while the fish is moving (and so visual information is available), but the action is not target-directed but rather directed towards a button in an attempt to make the net intersect the fish. In addition, the action is ballistic rather than continuously controlled: Once the net is released, it cannot be repositioned or affected in any way by the participant. Some have theorized that the action stream is mostly involved in the continuous guidance of action, rather than in the initial movements (Glover, 2004). Thus it could be the case that both explicit judgments and the action-based measure of net release time both show the action-specific effect because they are both driven by the same perceptual information, namely information in the cognitive or temporal pathway.

4.2 Non-Perceptual Explanations for Action-Specific Effects

The action-specific account of perception claims that perception is influenced by the perceiver's ability to act (Witt, 2017). Alternative explanations have also been offered. For example, one alternative is that perception is unaffected but responses reveal an influence because the responses are influenced by demand characteristics (Durgin et al., 2009; Durgin, Klein, Spiegel, Strawser, & Williams, 2012; Firestone & Scholl, 2016a, 2016b; Shaffer, McManama, Swank, & Durgin, 2013; Woods, Philbeck, & Danoff, 2009). It seems unlikely that demand characteristics could explain the results in the fishing task. As one piece of evidence, when feedback was given about the accuracy of speed judgments in a task similar to the fishing task in which participants attempted to block a ball by continuously controlling various sized paddles (known as the Pong task), the height of the paddle continued to influence speed judgments despite the feedback (King, Tenhundfeld, & Witt, 2017). As another piece of evidence, after completing the Pong task, participants were questioned whether or not they could guess the hypothesis (Witt, Tenhundfeld, & Tymoski, 2018). Only 25% guessed that a critical measure related to the height of the net (called a paddle in that task), and an additional 25% guessed the critical measure when probed about factors that might influence perceived speed. However, the action-specific effect was similar for these participants as for those who did not correctly guess the hypothesis. Furthermore, in a second study, participants were explicitly told the hypothesis and told to resist it, yet their perceptual judgments were similarly influenced by their abilities.

Another alternative explanation for these action-specific effects is that memory, rather than perception, is influenced. For example, in the original study on softball players, the participants estimated ball size in the absence of the ball, thus their judgments were made from memory (Witt & Proffitt, 2005). Support for a memory-based explanation comes from research on marble throwing (Cooper, Sterling, Bacon, & Bridgeman, 2012). In one study, participants attempted to throw marbles into a hole cut out of a box. After each throw, participants estimated the size of the hole. For some participants, the hole was still visible so the judgment was based on perceived size. For other participants, the hole was not visible, so the judgment was based on remembered size. After successful throws, participants judged the hole to be bigger than after unsuccessful throws, but only for the group that made judgments based on remembered size. The authors concluded that action-specific effects might be due to memory, rather than perception.

Although their claim of memory as opposed to perception was applied specifically to action-specific effects on judgments of object size, it is worth considering this claim with respect to all action-specific effects, including the fishing task. The explicit judgments of fish speed were made after the fish was no longer moving, and so could be explained by either a perception or a memory-based explanation. However, releasing the net was done while the fish was still moving, thereby ruling out the involvement of memory. Furthermore, it is unlikely that in the experiment for which no explicit judgments were made of fish speed that participants even inferred that the study was about perception. In hindsight, it would have been good to have interviewed participants about their inferences from the study, but given that previous studies showed participants had little insight anyway, it is likely these participants would not have guessed the study's purpose either. Together, these studies help make a compelling case that a person's ability to block the fish genuinely influences perceived speed of the fish.

4.3 Conclusions

Action-specific effects have been documented across perceptual judgments of a wide range of spatial properties including size, slant, distance, height, shape, and speed (Witt, 2011, 2017, in press). However, most research has utilized explicit judgments of the spatial property. Here, an action measure was used, namely the time to release the net to catch the fish. Net release time was influenced by the ease to catch the fish, as manipulated by height of the net. When the fish were easier to catch because the net was bigger, participants judged the fish as moving slower and also waited longer to release the net than when the net was smaller. This convergence across explicit judgments and action measures leads to several conclusions. First, it helps rule out alternative explanations related to memory given that the net was released while the fish was visibly moving. Second, it helps rule out alternative explanations related to demand characteristics given that the study's aims to explore perception was not obvious in the case for which no explicit speed judgments were made. Third, if explicit judgments and net release time tap into separate perceptual processing streams, such as the cognitive and action maps respectively, the convergence between the two measures suggests action's effect on perception occurs at early visual processing stages (cf. Dyde & Milner, 2002). There is little work to date on the neural mechanisms underlying action-specific effects. If these effects indeed occur in early visual processing stages, this suggests a mechanism by which information about a person's ability to act feeds back into early visual areas such as area MT.

Authors Note

Jessica K. Witt, Department of Psychology, Colorado State University, Fort Collins, CO 80523.

This paper is dedicated to Bruce, of course! This work was supported by grants from the National Science Foundation (BCS-1314162, BCS-1348916, BCS-1632222).

Please address correspondence to Jessica Witt, Colorado State University, 241 Behavioral Sciences Building, Fort Collins, CO 80523 USA. Email: Jessica.Witt@ColoState.edu.

References

Bhalla, M., & Proffitt, D. R. (1999). Visual-motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance, 25*(4), 1076-1096.

Bridgeman, B. (1991). Complementary cognitive and motor image processing *Presbyopia research: From molecular biology to visual adaptation* (pp. 189-198). New York, NY: Plenum Press.

Bridgeman, B., Gemmer, A., Forsman, T., & Huemer, V. (2000). Processing spatial information in the sensorimotor branch of the visual system. *Vision Research, 40*, 3539-3552.

Bridgeman, B., Kirch, M., & Sperling, A. (1981). Segregation of cognitive and motor aspects of visual function using induced motion. *Perception & Psychophysics, 29*(4), 336-342.

Bridgeman, B., Lewis, S., Heit, G., & Nagle, M. (1979). Relation between cognitive and motor-oriented systems of visual position perception. *Journal of Experimental Psychology: Human Perception and Performance, 5*, 692-700.

Bridgeman, B., Peery, S., & Anand, S. (1997). Interaction of cognitive and sensorimotor maps of visual space. *Perception & Psychophysics, 59*(3), 456-469.

Cooper, A. D., Sterling, C. P., Bacon, M. P., & Bridgeman, B. (2012). Does action affect perception or memory? *Vision Research, 62*, 235-240. doi: 10.1016/j.visres.2012.04.009

Dassonville, P., Bridgeman, B., Bala, J. K., Theim, P., & Sampanes, A. (2004). The induced Roelofs effect: two visual systems or the shift of a single reference frame? *Vision Research, 44*(6), 603-611.

Durgin, F. H., Baird, J. A., Greenburg, M., Russell, R., Shaughnessy, K., & Waymouth, S. (2009). Who is being deceived? The experimental demands of wearing a backpack. *Psychonomic Bulletin & Review, 16*(5), 964-969. doi: 10.3758/PBR.16.5.964

Durgin, F. H., Hajnal, A., Li, Z., Tonge, N., & Stigliani, A. (2010). Palm boards are not action measures: An alternative to the two-systems theory of geographical slant perception. *Acta Psychologica, 134*(2), 182-197.

Durgin, F. H., Klein, B., Spiegel, A., Strawser, C. J., & Williams, M. (2012). The social psychology of perception experiments: Hills, backpacks, glucose, and the problem of generalizability. *Journal of Experimental Psychology: Human Perception and Performance, 38*, 1582-1595.

Dyde, R. T., & Milner, A. D. (2002). Two illusions of perceived orientation: one fools all of the people some of the time; the other fools all of the people all of the time. *Experimental Brain Research, 144*(4), 518-527. doi: 10.1007/s00221-002-1065-1

Firestone, C., & Scholl, B. J. (2016a). Cognition does not affect perception: Evaluating the evidence for 'top-down' effects. *Behavioral and Brain Sciences, 39*, e229. doi: 10.1017/S0140525X15000965

Firestone, C., & Scholl, B. J. (2016b). Seeing and thinking: Foundational issues and empirical horizons [response to commentators]. *Behavioral and Brain Sciences, 39*, e264.

Glover, S. (2004). Separate visual representations in the planning and control of action. *Behavioral and Brain Sciences, 27*(1), 3-24.

Gray, R. (2013). Being selective at the plate: Processing dependence between perceptual variables relates to hitting goals and performance. *Journal of Experimental Psychology: Human Perception and Performance, 39*(4), 1124-1142.

King, Z. R., Tenhundfeld, N. T., & Witt, J. K. (2017). What you see and what you are told: Feedback does not diminish action-specific perception. *Psychological Research*. doi: 10.1007/s00426-017-0848-8

Milner, A. D., & Goodale, M. A. (1995). *The Visual Brain in Action*. New York: Oxford University Press.

Paillard, J. (1987). Cognitive versus sensorimotor encoding of spatial information. In P. Ellen & C. Thinus-Blanc (Eds.), *Cognitive processes and spatial orientation in animal and man, Vol. 1: Experimental animal psychology and ethology* (pp. 43-77). Dordrecht, Netherlands: Springer Netherlands.

Proffitt, D. R., Bhalla, M., Gossweiler, R., & Midgett, J. (1995). Perceiving geographical slant. *Psychonomic Bulletin & Review, 2*(4), 409-428.

Shaffer, D. M., McManama, E., Swank, C., & Durgin, F. H. (2013). Sugar and space? Not the case: Effects of low blood glucose on slant estimation are mediated by beliefs. *i-Perception, 4*, 147-155.

Singmann, H., Bolker, B., Westfall, J., & Aust, F. (2017). afex: Analysis of Factorial Experiments. from https://CRAN.R-project.org/package=afex

Team, R. C. (2017). R: A language and environment for statistical computing. Retrieved from https://www.r-project.org

Trommershauser, J., Maloney, L. T., & Landy, M. S. (2003). Statistical decision theory and the selection of rapid, goal-directed movements. *Journal of the Optical Society of America A, 20*(7), 1419-1433.

Trommershauser, J., Maloney, L. T., & Landy, M. S. (2008). Decision making, movement planning, and statistical decision theory. *Trends in Cognitive Sciences, 12*, 291-297.

Ungerleider, L. G., & Mishkin, M. (1982). Two cortical visual systems. In D. J. Ingle, M. A. Goodale & R. J. W. Mansfield (Eds.), *Analysis of Visual Behavior* (pp. 549-586). Cambridge, MA: The MIT Press.

Vishton, P. M., Sephens, N. J., Nelson, L. A., Morra, S. E., Brunick, K. L., & Stevens, J. A. (2007). Planning to reach for an object changes how the reacher perceives it. *Psychological Science, 18*, 713-719.

Witt, J. K. (2011). Action's Effect on Perception. *Current Directions in Psychological Science, 20*(3), 201-206. doi: 10.1177/0963721411408770

Witt, J. K. (2017). Action potential influences spatial perception: Evidence for genuine top-down effects on perception. *Psychonomic Bulletin & Review*.

Witt, J. K. (in press). Spatial biases from action. In T. Hubbard (Ed.), *Spatial Biases*. Cambridge, MA: Cambridge University Press.

Witt, J. K., & Proffitt, D. R. (2005). See the ball, hit the ball - Apparent ball size is correlated with batting average. *Psychological Science, 16*(12), 937-938. doi: 10.1111/j.1467-9280.2005.01640.x

Witt, J. K., & Proffitt, D. R. (2007). Perceived slant: A dissociation between perception and action. *Perception, 36*(2), 249-257. doi: Doi 10.1068/P5449

Witt, J. K., & Sugovic, M. (2013). Catching ease influences perceived speed: Evidence for action-specific effects from action-based measures. *Psychonomic Bulletin & Review, 20*, 1364-1370.

Witt, J. K., Sugovic, M., & Dodd, M. D. (2016). Action-specific perception of speed is independent of attention. *Attention, Perception, & Psychophysics, 78*(3), 880-890. doi: 10.3758/s13414-015-1047-6

Witt, J. K., Tenhundfeld, N. L., & Tymoski, M. J. (2018). Is there a chastity belt on perception? *Psychological Science, 29*(1), 139-146.

Woods, A. J., Philbeck, J. W., & Danoff, J. V. (2009). The various perceptions of distance: an alternative view of how effort affects distance judgments. *Journal of Experimental Psychology: Human Perception and Performance, 35*(4), 1104-1117. doi: 10.1037/a0013622