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A Visuomotor Skill Model for Energetic Costs Effects in Picture Perception

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Abstract (120)

Assessments of distance and slope are influenced by the energetic and emotional costs of anticipated actions. Participant accounts of narrative engagement suggest a means to evaluate whether these are perceptual effects or artifacts of the way participants judge the difficulty of anticipated tasks. Participant accounts suggest viewers simulate events depicted in pictures from the perspectives of their characters. We predicted that changes in the interpreted costs of actions depicted in pictures would be reflected in line drawing copies of their spatial layout demonstrating a correlation between the costs of depicted actions and the perceived extent of the depicted landscape. Our results confirm this prediction for energetic costs, $F(1,43) = 15.771$, $p < .001$, but not for emotional costs.

Effects of Behavioral Costs of Depicted Actions on Apparent Slope & Distance in Picture Perception

The maps Meriwether Lewis and William Clark produced while exploring the vast wilderness of the American Northwest exhibit a curious error: distances between landmarks are systematically overestimated where journal records report that travel was rough and hilly (Stefanucci, Proffitt, Banton, & Epstein, 2005). These systematic cartographic distortions reflect a robust set of perceptual effects attributable to the variable costs of acting in different environments.¹ A range of recent studies (Bhalla & Proffitt, 1999; Proffitt, Creem, & Zosh, 2001; Proffitt, Stefanucci, Banton, & Epstein, 2003; Stefanucci, Proffitt, Clore, & Parekh, 2008; Witt, Proffitt & Epstein, 2005; Witt & Proffitt, 2008) demonstrate that apparent slope and egocentric distance are influenced by three non-optical factors: the energetic costs of acting (e.g., fatigue and expected task difficulty), the emotional costs of acting (e.g., fear and anxiety), and physiological constraints on the capacity of an organism to perform an action (e.g., the extent of reach or the graspability of a tool). These effects generalize to interactions with virtual environments (Stefanucci et al, 2005) and cases in which participants merely imagine a change in their potential capacity for action (Witt & Proffitt, 2008). The results of these studies demonstrate that perception does not encode the structure of environmental features per se, but rather the relative behavioral costs of engaging in a particular action.

The behavioral costs of actions are determined by the conjunction of several factors: environmental features (e.g., slope or distance), the physiological states of agents (e.g. fatigue, fitness, or encumbrance), and the psychological states of agents

(e.g., anxiety and self-report of health). Slope perception provides the clearest example of these effects. Participants overestimate the slopes of hills in both verbal assessments and visual matching tasks: 5° hills appear on average to normal perceivers to be 10°, 10° degree hills look to be 30°, and overestimations of slope are exaggerated when participants are tired after a long run or encumbered by a heavy backpack (Proffitt, 2006). Distance estimations are similarly exaggerated in verbal and visual assessments when participants are encumbered by a backpack or asked to throw a heavy ball to a target (Proffitt et al, 2003; Witt, Proffitt, & Epstein, 2004). The rate of overestimation of slope and distance is smaller among physically fit populations of varsity athletes than non-athletic college students, and distance and slope assessments among elderly participants are correlated with self-perception of health (Bhalla & Proffitt, 1999). These effects also generalize to the emotional costs of actions. Stefanucci et al (2008) have shown that there is a positive correlation between subjective reports of anxiety associated with descending hills on skateboards and assessments of apparent slope and egocentric distance. Finally, these effects are limited to actions agents anticipate performing themselves. Witt et al (2004).

The results reported by Proffitt and his colleagues are compelling. However, one can question whether they reflect changes in the way participants perceive slope and distance in their environment, or are instead artifacts of the way participants judge the difficulty of anticipated tasks. In order to evaluate this alternative hypothesis one needs a method to directly measure the spatial metric of perception. One means to do so is to ask participants to sketch/copy the rough spatial layout of what they perceive as accurately as possible. In this type of task participants

continuously compare what they have drawn against what they perceive.

Comparisons of the spatial extent of their drawings across different interpretations of the energetic and emotional costs of anticipated actions can, therefore, be interpreted as a record of change in perceived slope and egocentric distance.

Philosophical theories of narrative understanding suggest a novel way to implement this strategy. Witt and Proffitt (2008) have shown that energetic cost effects in perception are the result of, and so demonstrate a role for, tacit motor simulation in action planning. Witt defines motor simulation as the act of imagining, either covertly or explicitly, an action without necessarily executing it. More concretely, motor simulation is the act of running a motor program offline, or simulating an action from a first person perspective by activating areas of premotor cortex associated with motor planning and preparation (Decety, 1996). Participant accounts of narrative understanding argue that viewers, spectators, and readers come to comprehend a narrative painting, film, drama, or work of fiction by adopting the vantage points and psychological perspectives of its central characters and imagining, or simulating, their depicted beliefs, desires, and actions from a first-person point of view (Goldman, 2006). Participant accounts are contrasted against observer accounts which argue to the contrary that we come to understand the content of a narrative picture, film, drama, or work of fiction from a third-person point of view (Carroll, 1997/2001; Kieran, 2003). A common theme in these latter types of theories is that spectators and readers are able to infer the content of narrative artworks using schema for actions and events encoded in episodic memory along with tacit folk psychological theories about the relationship between behavior and the beliefs and

desires of others. However, despite their disagreements, few researchers see the question of our ability to understand the beliefs, motives, and actions of characters as an all or nothing matter between simulation and inference. Rather, the debate between participant and observer accounts is a debate about the relative informational demands of narrative understanding in different contexts (Carroll, 1997; Kieran, 2001; Neill, 1996).

We do not explicitly recognize energetic and emotional costs effects in ordinary perceptual contexts. Therefore, we lack the type of declarative knowledge necessary for an inferential, or third person, understanding of how changes in the costs of a depicted action would change the apparent extent and egocentric distance of a landscape for a character. This entails that the presence of energetic or emotional costs effects in picture perception would demonstrate that viewers had adopted the vantage point and psychological perspective of the central character and simulated, or imaginatively anticipated, performing the depicted action. We hypothesized that energetic and emotional costs effects would generalize to picture perception, demonstrating that behavioral costs effects reflect genuine changes in perceived slope and distance associated with the role played by motor simulation in action planning.

Energetic and Emotional Costs in Picture Perception

We used four paintings by Andrew Wyeth to test our hypothesis: Brown Swiss² (practice), East Waldoboro³ (practice), Christina's World⁴ (energetic costs), and Winter, 1946⁵ (emotional costs). All four paintings are similar in luminance profile and hue. The two target images, Christina's World and Winter, 1946 are similar in

compositional structure. These latter paintings appear to art historically naïve viewers as realistic depictions of ordinary, emotionally neutral events. However, the central subjects of the paintings were real individuals who suffered from physical disabilities and personal circumstances that influence the energetic or emotional costs of the depicted events. We predicted that copies of the spatial layout of the target images would differ across interpretations of the energetic and emotional costs of depicted actions, indicating that the introduction of salient biographical information had caused viewers to perceive the slopes of depicted hills in the paintings as steeper and the distance between key landmarks as longer.

Energetic Costs

Viewers often report that Christina's World depicts a normal young woman lying in a field.⁶ However, the subject of the painting, Christina Olsen, had been disabled since she was a small child. Although she could stand on the sides of her ankles and move about, painfully, but she could only do so for short distances. Wyeth reports that the painting depicts Christina crawling home across the field in the painting. We predicted that the introduction of this information would change the way participants interpreted the energetic costs of the depicted action and cause them to perceive the distance from Christina Olsen to the house as longer and the slope of the hill as steeper.

Participants. Fifty-two participants were recruited from the general Franklin & Marshall College population (16 men and 36 women; 48 undergraduates and 4

faculty), and compensated with lab credit or paid \$5 for their participation. All participants gave consent.

Materials. Participants were provided with four sharpened 8b (soft) drawing pencils along with a pencil sharpener and an Artgum eraser to facilitate their drawings. We used a ceiling mounted VGA projector to project the images onto a screen in a darkened room. Participants sat at a long utility table seven feet from the screen and made their drawings on 24" x 36" newsprint sheets. The projected size of each image (approximately 25" x 40") was scaled to match the visual size of the drawing sheet. Participants were positioned so that the center of each image was approximately 18" above their line of sight.

Design & Procedures. We used a 2 (costs) x 3 (time) between subjects factorial design to evaluate the effects of interpreted energetic costs and drawing time on change in the apparent extent of the landscape in Christina's World. Participants were divided into two costs groups, targets and controls. Within each of the costs groups participants were assigned to either a 30-second, 1-minute, or 3-minute drawing time condition. All participants made two copies of Christina's World (drawing 1 and drawing 2). We manipulated the energetic costs of the depicted action within the target group by having participants read a short biographical passage about Christina Olsen and the painting prior to their second drawing. Change in extent was calculated by subtracting the extent of drawing 2 from the extent of drawing 1. For data analysis we compared the mean change in extent (in^2) between the target and control groups.

The procedures were identical within each condition. All participants were tested individually. Each participant made four drawings. We told participants in advance that the first two drawings were for practice and that they might see the same image twice, but we did not tell participants that they would draw the same target image twice. Images were presented for either 30 seconds, 1 minute, or 3 minutes while participants made their copies. At the end of the timing period the image disappeared and was replaced by a black screen. Participants were told that their task was to make as accurate a copy of the spatial layout of the painting as possible, as if they were making a preliminary drawing onto a canvas to mark out the positions of significant features of a landscape. We encouraged them to use abstractions to facilitate their drawings (e.g., rectangles for buildings and stick figures for people) and told them not to worry about how realistically the figures in their drawings matched the figures in the original. These instructions were reinforced prior to each drawing.

The order of presentation of the images was always the same. Participants drew Brown Swiss first, followed by East Waldeboro and Christina's World. They filled out a written survey after completing their first drawing of Christina's World (drawing 1) to screen for drawing skill, general knowledge of art history, and interpretation of behavioral costs, after which they took an enforced two minute break. The survey and break served as distractor tasks to take their minds off of drawing 1. Participants in the target group read a short biographical passage at the end of the break that described Christina Olsen's disability and reported that she was depicted crawling home from a visit to her parents' graves in the painting. We

reinforced the instruction to copy the spatial layout of the image presented as accurately as possible for all participants prior to drawing 2. Participants filled out a written survey after completing their second drawing of Christina's World (drawing 2) to screen for familiarity with the paintings, familiarity with Wyeth's work, familiarity with biographical knowledge salient to the events depicted in the paintings, and to evaluate change in the interpretation of the costs of the action depicted in the painting.

Results. We defined the extent of Christina's World as the area of the triangle formed by the head of the figure, the front corner of the house (primary landmark), and the point where a vertical line bisecting the head of the figure intersected with the horizon (secondary landmark). This measure enabled us to capture changes in both the egocentric distance between the subject of the painting and the target of her action and the slope of the hill. Distances appear longer on hills and exaggerations of egocentric distance on hills are correlated with changes in both apparent slope and the energetic costs of acting. Therefore, we hypothesized that the apparent distance to the secondary landmark would vary with the apparent slope of the hill even though it was not the target of the depicted action. We threw out drawings in which any of these features were omitted. There were 49 remaining pairs of drawings following this procedure.

We ran a 2 (costs) x 3 (time) between subjects ANOVA with change in extent (in^2) as the dependent variable.⁷ There was a significant main effect for costs, $F(1,43) = 15.771$, $p < 0.001$. Participants in the target group expanded the extent of the

landscape in drawing 2 relative to drawing 1 to a greater extent than participants in the control group (table 1). There was a significant main effect for time, $F(2,43) = 4.585, p < 0.01$. The interaction between condition and time was significant, $F(2,43) = 10.452, p < 0.001$, indicating that the effect of costs was influenced by the amount of time participants had to make their drawings.

In order to evaluate the interaction between costs and time, we ran a between-subjects ANOVA comparing the values of the costs variable among the drawing time conditions within each of the target and control groups. There was no significant difference in performance among participants in the 30-second, 1-minute, and 3-minute target conditions, $F(2,27) = 1.059, p = 0.361$. However, drawing time did influence performance in the control condition, $F(2,16) = 15.791, p < 0.001$. The mean change in extent (in^2) for the 30-second control condition was significantly different than each of the 1-minute (md = 25.228, se = 5.370), $p < 0.001$), and 3-minute (md = 24.483, se = 5.370, $p < 0.001$) control groups in pairwise comparisons (figure 1, table 1). The differences between the 1-minute and 3-minute control groups were not significant (md = 0.744, se = 6.089, $p = 0.904$).

Insert Figure 1 about here

Insert Table 1 about here

Discussion. The introduction of biographical information that increased the energetic costs of the action depicted in Christina's World caused participants to draw depicted distances as longer in their copies, indicating that participants in the target group

perceived the extent of the landscape depicted in the painting as longer in their second drawings. These results, therefore, demonstrate that energetic cost effects generalize to picture perception and support the claim that behavioral costs effects reflect genuine changes in perceived slope and distance.

We introduced the drawing time variable in order to evaluate whether viewing time would influence behavioral costs effects in perception. We hypothesized that participants in the 3-minute target condition would have sufficient time to correct perceptual distortions due to the energetic costs of depicted actions. We expected, as a result, that energetic costs effects would be greater for the 1-minute than the 3-minute target condition, and that the drawings of participants in the 3-minute condition would be closer to accurate. This was the case. But, interestingly, the 3-minute target condition drawings reflected the structure of distance assessments, not the spatial structure of Christina's World per se. There is a critical difference between slope and distance perception. Apparent egocentric distance increases as the energetic cost of actions increase, just as in the case of slope. However, normal perceivers underestimate distances in the environment in standard conditions. Overestimations of distance due to energetic cost effects, unlike the case of slope, more closely approximate the distance to the target.⁸ Participants in the 1-minute target condition expanded the extent of the depicted landscape in both of their drawings. Participants in the 3-minute target condition underestimated the extent of the landscape on average in their first drawings (i.e., prior to the introduction of information about Christina Olsen's disability) and were closer to accurate in their second, or increased energetic costs, drawings (table 2). Therefore, although differences between the 1-

and 3-minute target conditions were not significant, the performance of the 3-minute condition more closely matches the structure of distance assessments in ordinary perceptual contexts. Given that these participants had sufficient time to analyze the spatial structure of the painting and correct for any recognizable errors in their copies, these results provide further support for the claim that energetic costs effects reflect genuine changes in perceived slope and distance.

Insert Figure 2 about here

Inset Table 2 about here

The interaction between costs and time is explained by the performance of the 30 second control condition who, contrary to our prediction, expanded the landscape to a greater extent than participants in the 30 second target condition (figure 1, table 1). We had expected that participants in the 30-second group would find the copying task difficult, and that their performance would be less consistent than participants in the 1 minute and 3-minute conditions. Cohen (2005) reports that individuals without significant drawing skills have difficulty copying even simple line drawings at timings shorter than 1-minute. Cohen identifies gaze frequency as the source of this difficulty for inexperienced copyists. Skilled copyists adopt regimented gaze strategies. Novice copyists, on the other hand exhibit erratic gaze strategies. They, therefore, do not look back and forth efficiently between their copies and the original at drawing times shorter than one minute. We expect that differences in gaze frequency explain the difference in performance between the 30 second control

condition and both the 1 and 3 minute control conditions. We also hypothesize that gaze strategy can explain why we did not observe similar differences between the 30 second and either of the 1 minute or 3 minute target conditions. We expect that the introduction of biographical information about Christina Olsen prior to the second drawing enhanced the attention of participants in the 30 second target condition and enabled them to overcome difficulties ordinarily associated with gaze frequency for novice copyists.

Reverse Energetic Costs

The purpose of this experiment was to determine whether we could reverse the energetic costs effects induced by the biographical story participants in the target energetic costs group read prior to producing their second drawings. Energetic costs effects contribute to action planning by tacitly encoding the relative costs of anticipated actions in particular environmental context. We hypothesized that if increases in the interpreted energetic costs of depicted actions caused increases in the apparent extent of depicted landscapes in picture perception, decreases in the interpreted energetic costs of depicted actions should cause decreases in the apparent extent of depicted landscapes. We predicted, as a result, that decreasing the interpreted energetic costs of the action depicted in Christina's World would cause participants to perceive the slope of the hill depicted in the painting as shallower and the distance from the subject to the house as shorter.

Participants. Nine participants were recruited from the general Franklin & Marshall

College population (3 men and 6 women), and compensated with lab credit or paid \$5 for their participation. All participants gave consent.

Design & Procedures. We used a between subjects design to measure the effects of decreasing the interpreted energetic costs of depicted actions on the apparent extent of the depicted landscape in Christina's World. The materials, design, and procedures were the same as those for the 1-minute energetic costs target condition with one exception. Participants were asked to read the biographical information that we used in the energetic costs target condition prior to their first drawing. Prior to their second drawing participants were asked to read a second passage that described the depicted action as a more familiar regular event in Christina Olsen's life with lower energetic costs. The passage described the subject of the painting as returning from her vegetable garden, and explained that she and her brother farmed the blueberries that grew in the field each season. The story also explained that the common belief that Christina is depicted crawling home from a rare visit to the family graveyard is false.⁹ We compared the results of these procedures with the results from the 1 minute energetic costs target group.

Results. We threw out drawings in which any of the features used to define the extent of the depicted landscape in Christina's World were omitted. There were 7 remaining pairs of drawings following this procedure. We ran a between subjects ANOVA comparing the mean change in extent (in²) between the Reverse and 1-minute target conditions. The mean change in extent in the Reverse condition was not significantly

different from the mean change in extent in the 1-minute target condition, $F(1,15) = 0.785$, $p = 0.390$ (see [figure 1](#)). Furthermore, participants in the Reverse condition did not truncate, but slightly expanded the landscape in drawing 2 relative to drawing 1 ($\underline{m} = 2.806$, $\underline{sd} = 19.023$). Therefore, we were not able to reverse the energetic costs effects associated with the story participants in the target energetic costs group read prior to producing their second drawings.

Discussion. We were not able to reverse the energetic costs effects observed in the 1-minute energetic costs condition. We expect that these results can be explained in terms of the way participants in the Reverse condition interpreted the relative costs of the actions described in the two stories they read. We expected that participants would interpret a regular visit to the vegetable garden as less energetically costly than a rare visit to the family plot. However, participants in the Reverse condition expanded the landscape in drawing 2 relative to drawing 1. This suggests that they interpreted crawling home from a regular visit to the vegetable garden as more energetically costly than crawling home from a rare visit to the family graveyard. Furthermore, although participants in the Reverse condition expanded the landscape in drawing 2 relative to drawing 1, they did not do so to as great an extent as participants in the 1 minute energetic costs target condition ($\underline{md} = -6.184$, $\underline{se} = 6.980$). This suggest that participants interpreted the difference in costs between lying in a field and crawling home as greater than the difference in costs between the two actions described in the reverse condition. Therefore we attribute the null result in this experiment to a failure to adequately differentiate the energetic costs of the actions

described in the stories participants in the Reverse condition read prior to their first and second drawings.

Emotional Costs

The purpose of this experiment was to determine if energetic costs effects generalize to the emotional costs of depicted actions in picture perception. Viewers often report that Winter 1946 depicts a boy playfully running down a hill.¹⁰ However, the boy depicted in Winter, 1946 witnessed Wyeth's father and young nephew get run over by a train just beyond the crest of the hill. Wyeth reports that the painting symbolizes the anxiety he felt after losing his father. We predicted that the introduction of this information would change the way participants interpreted the energetic costs of the depicted action and cause them to perceive the distance from the subject to the center of the bush at the point where the road meets the horizon as longer and the slope of the hill as steeper.

Participants. Thirty-one participants were recruited from the general Franklin & Marshall College population (9 men and 22 women; 26 undergraduates and 5 faculty), and compensated with lab credit or paid \$5 for their participation. All participants gave consent.

Design and Procedures. We used a 2 (costs) x 2 (time) between subjects factorial design to evaluate the effects of change in interpreted energetic costs and drawing time on change in the apparent extent of the landscape in Winter, 1946. We had

hypothesized that participants in the 3 minute drawing time condition would have ample time to analyze the depicted landscape in the paintings and correct perceptual distortions due to the energetic costs of depicted actions. Therefore we chose to use only 30 second and 1 minute drawing conditions for the emotional costs experiment. The materials, design, and procedures were the same as in the energetic costs experiment except that we used Winter, 1946 as our target image and participants in the target group were asked to read a passage that described the boy in the painting as anxiously fleeing the scene of the accident that killed Wyeth's father and young nephew prior to their second drawing and symbolized Wyeth's own anxiety at the time.

Results: We defined the extent of Winter, 1946 as the area of the triangle formed by the head of the figure, the center of the bush at the point where the road meets the horizon (primary landmark), and the peak of the hill (secondary landmark). This measure enabled us to capture changes in both the egocentric distance between the subject of the painting and the target of his action and the slope of the hill. We threw out drawings in which any of these features were omitted. There were 28 remaining pairs of drawings following this procedure. Change in extent was calculated by subtracting the extent of drawing 2 from the extent of drawing 1. For data analysis we compared the mean change in extent (in^2) between the target and control groups.

We ran a 2 (condition) x 2 (time) between subjects ANOVA with change in extent (in^2) as the dependent variable. There was no significant main effect for costs, $F(1,23) = 1.986$, $p = 0.172$. There was no main effect for time, $F(1,23) = 0.011$, $p =$

0.917 and the interaction between condition and time was not significant, $F(1,23) = 0.033$, $p = 0.857$. Neither changes in interpreted emotional costs of the action depicted in Winter, 1946 nor drawing time had a significant effect on participant drawings.

Discussion. Participants in the emotional costs target group expanded the landscape to a greater extent than participants in the emotional costs control group (figure 1, table 1). However, the differences between the two groups were not significant. Therefore, our results do not support the hypothesis that emotional costs effects generalize to picture perception. We hypothesize that complications with the stimuli were a significant contributing factor to the null result in this experiment. The boy in the painting is both running towards, and looking at, the viewer, engaging his or her attention. In contrast, the viewer is situated behind the figure in Christina's World. It may, as result, be harder to adopt the perspective of the figure in Winter, 1946. Further, we speculate that the eyes of the figure engaged the attention of viewers and inhibited their ability to adopt efficient gaze strategies (see above and Cohen, 2005). Finally, behavioral costs effects in perception are associated with anticipated actions (e.g., anxiety about descending steep slopes). The target of the anxiety attributed to the subject of the painting in the passage read by participants in the target group is not descending the slope, but rather an event that transpired beyond the crest of the hill behind him. Therefore, we hypothesize that participants in the target group did not experience a change in the emotional costs of the action depicted in the painting between drawing 1 and drawing 2.

Further Issues: Narrative Understanding and Appreciation

The results of the present study demonstrate that energetic cost effects generalize to picture perception and therefore support the claim that behavioral costs effects reflect genuine changes in perceived slope and distance. These results are consistent with and so lend support to an earlier model for premotor contributions to visual analysis and form recognition (Kozbelt & Seeley, 2007). Kozbelt (2001) reports that artists outperform non-artists in basic visual analysis tasks (e.g., gestalt completion tasks, embedded figure tasks, and recognizing the subjects of blurry photographs) and that their advantages in these tasks are correlated with drawing skill. Kozbelt & Seeley argue that reciprocal connectivity between premotor areas involved in motor preparation and prefrontal areas involved in both spatial working memory and selective attention facilitate the recognition of sets of visual features that support adequate depiction. These sets of visual features suffice for adequate depiction because they suffice for object recognition. In other words, learning to draw, a motor skill, facilitates seeing the world in terms of the affordances for drawing, a particular type of action, which in this particular case also confers an advantage in visual analysis and form recognition. Proffitt argues that energetic and emotional costs effects are a means to directly encode affordances for action in the spatial metric of perception (Proffitt, 2006). The results of the present study, therefore, suggest that our model for the role of motor simulation in perception for drawing generalizes to other types of actions and motor skills.

Our interpretation of the results of the present study rest on the validity of participant accounts of narrative understanding. One criticism of participant accounts

is that simulation is otiose in narrative contexts. The purpose of a text, drama, film, or representational painting is to explicitly represent a set of narrative cues that carry information necessary to reconstruct and comprehend depicted events (e.g., cues that enable a viewer to perceptually recognize the events and behaviors depicted in a painting). This entails that information sufficient to understand the behaviors, thoughts, and feelings of characters is explicitly represented in a successful artwork. Simulation is, therefore, not necessary, for narrative understanding, one need only recover cues sufficient to recognize the depicted event as of a type or as similar to some set of past events encoded one's own episodic memory (Carroll, 1997/2001; Kieran 2003).

The results of the present study challenge this view. Salient narrative details needed to recognize the event depicted in Christina's World were explicitly represented in the passages that participants in the target energetic costs group read prior to their second drawings. Nonetheless, we observed energetic costs effects in target group drawings indicating that participants simulated the depicted event from Christina Olsen's perspective. Therefore, our study demonstrates a larger role for simulation than countenanced by observer accounts of narrative understanding. These implications are consistent with general considerations about the cognitive costs of narrative engagement and event recognition in general. Despite the presence of explicit cues in a scene or narrative, the range of stored facts that one would need to recover from declarative knowledge to adequately model the dispositions and emotions of a character, or the environmental dynamics of a depicted action, is staggeringly large. Simulation is a tool that can be used to model the behavior of

agents and characters when this information is not explicitly available. Therefore, cognitive efficiency favors an approach to our understanding of dynamic events that attributes a significant role to simulation.

These considerations generalize to theories of narrative appreciation. A full appreciation of narrative turns on a deep understanding of character, or an ability to understand how a character's dispositions and emotions necessitate depicted actions. Participant and observer accounts differ in their assessment of the qualitative character of deep understanding. Participant accounts argue that deep understanding is a product of our capacity to empathize with characters (Coplan, 2004; Neill, 1996). Empathy relies on our capacity to adopt the psychological perspectives of others and imagine, or simulate, some aspect of their character or experience (Adolphs and Spezio, 2007; Goldman, 2006). Therefore, on the participant account, we are able to make sense of the twists and turns of a plot by embodying those aspects of characters that compel their depicted behaviors. The artistic value of a narrative, in turn, emerges from rich, empathic, imaginative events through which we encounter particular characters and reflect on their actions, dispositions, and emotions. Observer accounts argue, to the contrary, that the conjunction of explicit narrative cues and folk psychological schema for character types are sufficient for deep understanding. Therefore, they argue that simulation is otiose in the context of narrative appreciation.

The results of the present study challenge this claim of observer accounts as well. Narrative details sufficient for a deep understanding of Christina Olsen were explicitly represented in the passage that target group participants read prior to their second drawings. The observed energetic costs effects demonstrate, as a result, not

only that participants anticipated performing the depicted action, but also that they tacitly imagined the behavioral costs of the depicted action (i.e., what it would be like to perform the action) from Christina Olsen's vantage point and psychological perspective. Therefore, the results of our study favor an empathy-based model for narrative appreciation that attributes a significant role to simulation.

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Author Notes

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Footnotes:

1. Of course, we cannot rule out the alternative hypothesis that systematic spatial distortions in Clark's maps are due to a memory bias, and so do not reflect a genuine perceptual effect. However, it is a reasonable assumption that the maps were produced from careful field notes and sketches made while travelling the landscape. These notes and sketches would reflect Clark's perception of the landscape at the time he passed through it. If the assumption about Clark's methodology is sound, his systematic cartographic errors reflect the influences of the energetic and emotional costs of actions on perception. Nonetheless, this matter can only be resolved by returning to the field notes from the expedition.

2. See retrieved August 31, 2008:

<http://www.museumsyndicate.com/item.php?item=15617>.

3. See Corn, 1973, p. 100.

4. See retrieved February 18, 2009:

http://www.moma.org/collection/browse_results.php?criteria=O%3AAD%3AE%3A6464&page_number=1&template_id=1&sort_order=1.

5. See retrieved February 18, 2009:

http://www.ncmoa.org/collections/highlights/20thcentury/20th/1910-1950/039_lrg.shtml.

6. 51 of 56 participants described Christina Olsen as lying the field in surveys completed prior to the introduction of biographical information. None of the remaining five participants described her as either crawling or anticipating crawling home.

7. We used a Bonferroni adjusted alpha levels of 0.025 (0.05/3) for each of the energetic costs analyses.
8. See Witt et al., 2004, p. Figure 1.
9. See Merryman, 1998.
10. Only 2 of 28 participants attribute psychological distress to the boy running down the hill in Winter, 1946 in surveys completed prior to the introduction of biographical information.

Table 1

Mean Change in Extent (in²) between Drawing 1 and Drawing 2 (one-tailed)

Group	Targets		Controls	
	<u>m</u>	<u>sd</u>	<u>m</u>	<u>sd</u>
Energetic Costs (all) ^a	4.842	11.778	-4.798	15.654
30-seconds	1.455	15.027	8.284	8.138
1-minute	8.990	9.651	-16.944	6.615
3-minutes	4.079	9.776	-16.199	13.950
Reverse	2.806	19.023	8.990	9.651
Emotional Costs (all)	8.1117	20.160	-5.185	24.806
30-seconds	9.309	19.722	-5.505	30.011
1-minute	6.627	21.964	-4.785	20.967

^aEnergetic Costs (all) represents the mean change in extent (in)² for the combined 30-second, 1-minute, and 3-minute energetic costs groups.

Table 2.

Mean Extent (in²) of Target Group Energetic Cost Drawings and Christina's World

	1-minute	3-minute	<u>Christina's World</u>
Drawing 1	41.42	36.24	40.22
Drawing 2	50.41	40.32	

Figure Captions

Figure 1. Mean change in extent (in.²) for the 30-second, 1-minute, 3-minute, and Reverse energetic costs target and control conditions (*top*) and the 30-second and 1-minute emotional costs target and control conditions (*bottom*).

Figure 2. Example of drawing 1 (*top*) and drawing 2 (*bottom*) from the 1-minute target energetic costs condition. Participants in the target energetic costs group tended to draw a more pronounced crown to the hill in drawing 2 which we interpreted to indicate an increase in the perceived slope of the hill in the painting. Notice that Christina's ankles are depicted more accurately as frail and emaciated in drawing 2, and her left arm, which is not included in drawing 1, is extended in the act crawling.

Figure 1.

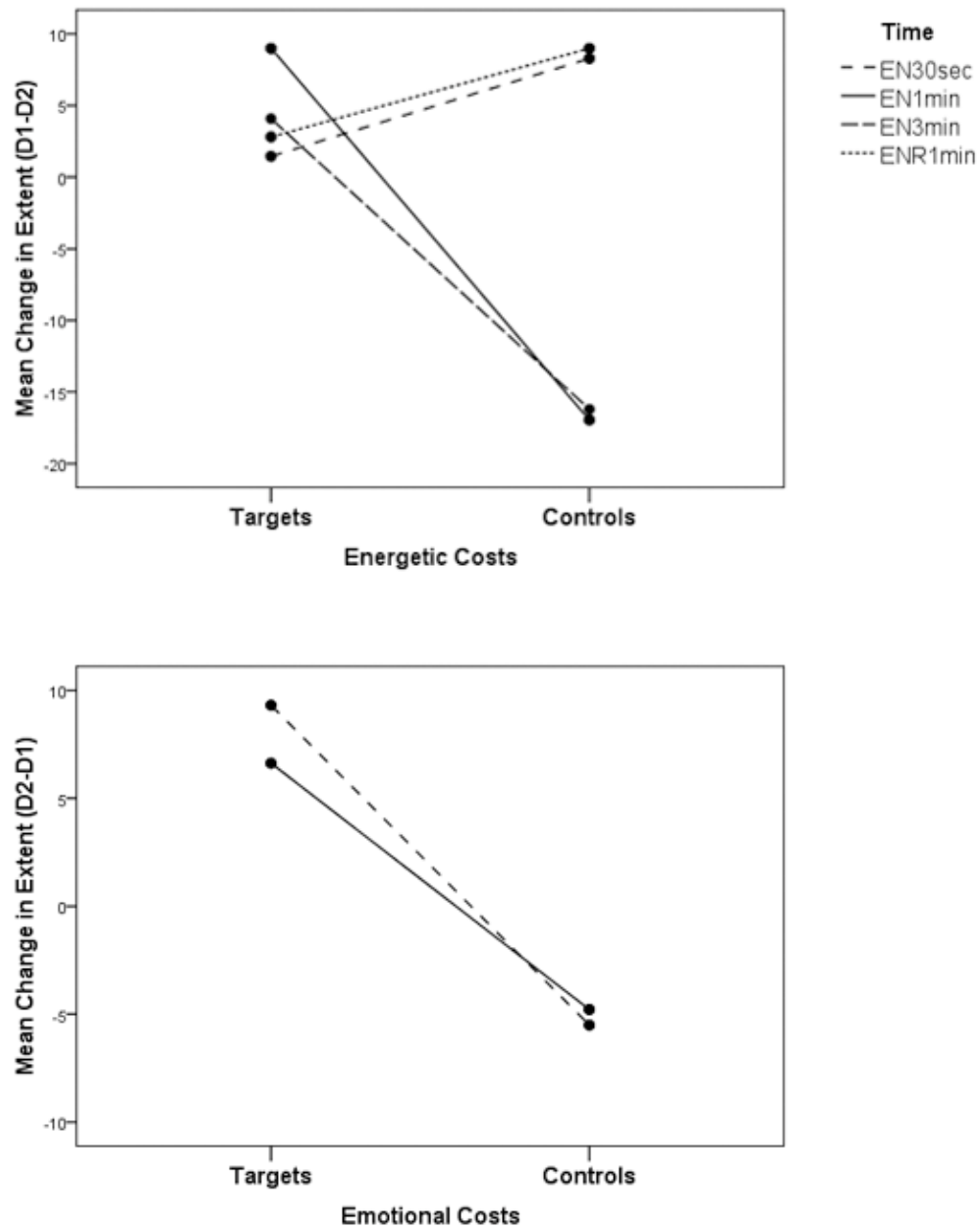


Figure 2.

