Linking Action and Perception: Theory and Application

Kelsey Carlson

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Kelsey Carlson

aus, Farnhamville, Iowa, USA

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Referent:	PD Dr. Agnieszka Wykowska
Korreferent:	Prof. Dr. Hermann Müller
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Synopsis

Theoretical Background

The Theory of Event Coding (TEC) proposed by Hommel, Müsseler, Aschersleben, & Prinz (2001) suggest that perception and actions share a common representational domain, therefore allowing for a bi-directional link between the two processes. However, in investigating these bi-directional action-perception links it has been found that actions can in some circumstances **impair** the perception of action-congruent stimuli (Müsseler and Hommel, 1997 a, b); while in other circumstances, actions can **facilitate** the perception of action-congruent stimuli (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012).

When one takes a closer look at these paradigms it can been seen that in the studies of (Müsseler and Hommel, 1997 a, b) the action-plan component consisted of left or right key presses, that the action-plan overlapped with the perceptual stimulus in regards to features (left or right), and that participants performed a discrimination task on the perceptual stimulus. In the studies of (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012) the action-plan component consisted of real-world actions (grasping or pointing), the action-plan overlapped with the perceptual stimulus in regards to dimensions, and the perceptual task required participants to perform a detection task for a target in a search array.

The Intentional Weighting Mechanism (IWM) proposed by (Hommel et al., 2001; Wykowska et al., 2009; Memelink & Hommel, 2013) attempts to explain how action and perception may interact through a common code. This common code is thought to link actively produced events and perceived events by holding the sensory-components of the two processes. These common codes are thought to be formed during action-planning and to consist of episodic memory traces or **event files** (Hommel, 2004). Event files are similar to a concept proposed by Wolfe & Bennett (1997) who discuss pre-attentive "object files" which consist of shapeless bundles of basic features.

Furthermore, it is suggested that when planning an action that stimuli which share dimensions with the planned action are given a higher weight and therefore processed with priority due to their relevance for later online adjustment of action control. However, the IWM does not address the issue of action-perception impairment found by (Müsseler and Hommel, 1997 a, b).

The first part of this dissertation (Chapters 2, 3, 4) used a modified version of the experimental paradigms of Wykowska et al. (2009 and Wykowska et al. (2011) to investigate impairment and facilitation effects in the context of real-world actions. Chapter 2 aimed to investigate both types of effects with real-world actions. Task one investigated how real-world actions effect perceptual processing when perceptual detection is required. Task two investigated how real-world actions effect perceptual processing when perceptual discrimination is required. Results of these tasks (perceptual detection and discrimination) are compared. Chapter 3 also investigates how real-world actions effect perceptual processing when perceptual discrimination is required. However, instead of performing a task that is related to visual attention (a visual search task, as in Wykowska et al., 2009), participants performed a task that required only processing of stimuli features and not attentional selection. Chapter 4 used the paradigm of Chapter 3 with the addition of ERP methodology. This chapter aimed to use ERP methodology to investigate how action planning can influence the different stages of perceptual processing required in a feature discrimination task.

The second part of this dissertation (Chapter 5) aims to move from investigating action and perception in the lab to applying knowledge of action and perception in a real-world environment. To this aim a robot named "CuDDler" (A*Star) was tested to see if it had the ability to enhance the joint attention skills of children with Autism Spectrum Disorder (ASD).

Overview of the Present Studies

The Intentional Weighting Mechanism: Perceptual Dimensions versus Features

Chapter 2 describes two tasks which investigate the effect of planning a real-world action (grasping or pointing) on perceptual processing in either a detection task which required perceptual processing at the dimension level (here dimension = size) or a discrimination task requiring perceptual processing at the feature level (small or large). This was done to investigate how the difference in perceptual task may lead to impairment or facilitation of perception of action-congruent stimuli with real-world actions.

In the first task participants were informed trial-by-trial if they should perform either a grasping or pointing movement to later be executed to a paper cup below the computer screen. After being cued which movement to plan they were presented with a detection task wherein they had to detect if a size target was present or absent among 27 other circles. In the second task the detection task was changed to a discrimination task. Here participants had to determine if the size target was small or large.

Comparison of RTs on the factors task type (detection vs. discrimination) and movement type (grasping vs. pointing) showed a main effect of task type and more interestingly an interaction between the factors. The main effect of task type showed participants being faster in the discrimination task than the detection task. This may simply be due to the fact that the discrimination task was performed on the second day, and therefore the participants had more experience with the task.

The effect of interest, the interaction between task type and movement type revealed that in the detection task when participants prepared a grasping movement they were marginally faster to detect a size target than when they had prepared a pointing movement. In the discrimination task when participants prepared a pointing movement they were significantly faster to discriminate the size of a target than when they had prepared a grasping movement.

The results of the detection task show the typical facilitation (congruency effect) seen before by other studies (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012). While the results of the discrimination task show interference effects similar to Müsseler and Hommel (1997 a, b), but now with real-world actions. In sum, these results suggest that when the task requires perceptual processing at the level of dimensions, action-related biases of perceptual processing can be observed in the form of facilitation (congruency) effects. However, when the task requires perceptual processing at the level of features, action-related biases of perceptual processing can be observed in the form of interference effects. These results give an insight into the different patterns of results across various paradigms showing action-perception links.

The Role of Feature Discrimination in Action-Perception Interference Effects

Chapter 3 describes an experiment designed to further investigate the role feature discrimination plays in action-perception interference effects. The current paradigm attempts to show that action-perception biases in feature-based processing, before seen in an attentional task (Carlson & Wykowska, in review, see Chapter 2), can be generalized to a lower-level perceptual task where attentional selection is not required.

In this experiment participants were informed block-wise if they should discriminate if two disks were the same or different on either luminance or size feature values. Again, on each trial participants were randomly informed if they should plan a pointing or grasping movement to be performed after the discrimination task.

The disks presented could either be physically identical (both the same size and luminance) or different on the irrelevant dimension (for example in the size blocks stimuli which were the same size, but different luminance) both of these set types required a response of “same” since they were the same on the relevant dimension. The third set type was different on the relevant dimension and the same on the irrelevant dimension (for example in the size blocks stimuli which were of different size, but same luminance) this set required a response of “different”. Since the two “same” set types created different signals they were analyzed separately. In both analysis d-primes were used to measure the participants’ sensitivity to the difference between the disks.

In the first analysis identical “same” and “different” sets were used to calculate d-primes. In this analysis a main effect of dimension was found with size eliciting a larger d-prime than luminance. This result is mostly likely due to size blocks being easier than luminance blocks. Also, a significant interaction between dimension (luminance vs. size) and movement type (grasping vs. pointing) was found. This showed that during luminance discrimination participants had higher sensitivity to the difference when they had prepared a grasping movement, relative to pointing. While during size discrimination participants had higher sensitivity to the difference when they had prepared a pointing movement, relative to grasping. In the second analysis irrelevant-dimension “same” and “different” sets were used to calculate d-primes. This analysis only showed a significant main effect of relevant dimension with size eliciting a larger d-prime than luminance. This might indicate that the irrelevant dimension was still processed to some extent and thus the effects might have cancelled out.

These results support the idea that action-perception interference effects occur when feature-based processing is required (Carlson & Wykowska, in review, see Chapter 2). The present study extends the previous findings by showing that the action-perception biases in feature-based processing generalize from an attentional task to a lower-level perceptual task where attentional selection is not required.

The Role of Feature Discrimination in Action-Perception Interference Effects: An EEG Study

Chapter 4 used the same paradigm as Chapter 3 with the addition of electroencephalography (EEG). Wykowska & Schubö (2012) found that when participants had to prepare a grasping or pointing movement, then detect a target based on its dimension, either size or luminance (block-wise), that in the luminance condition there was a more enhanced positivity in P1 across the occipital electrodes (O1/O2 and PO7/PO8) when a pointing movement was prepared relative to when a grasping movement was prepared. No significant effects were found in the size condition. Therefore, it was thought that in the current paradigm pre-selective weighting of dimensions would be reflected with a pattern that supports action-perception facilitation (congruency) effects in P1 (such as Wykowska & Schubö, 2012).

However, since the comparison task required discrimination of the features of the stimuli it was thought that later processing around the time of the N1 component would reflect action-perception interference effects. This component was of interest because, Vogel & Luck (2000) have shown that the inferoposterior component with its peak amplitude 140 – 180 ms post-stimulus at lateral occipital electrodes potentially reflects discrimination.

Again the disks could be presented in three different sets: 1. identical - “same”, 2. same relevant dimension, different irrelevant dimension – “same”, or 3. different relevant dimension, same irrelevant dimension – “different”. Due to a difference in trial type number per condition (size or luminance), conditions were analyzed separately and by trial type. So that for each condition (size or luminance) ANOVAs were conducted on movement type (grasping vs. pointing) and electrode. Finally, the factors condition (size vs. luminance), movement type (grasping vs. pointing), and electrode were compared on the identical – "same" trials.

The P1 component was analyzed 80 – 140 ms post-stimulus on the electrodes O1, O2, PO7, PO8. In the size condition on the same trials there was a main effect of movement with grasping having a more enhanced positivity than pointing. In the comparison of condition, movement type, and electrode site there was a main effect of condition with size having a more enhanced positivity than luminance and an interaction of condition and movement. Both pointing and grasping were significantly more positively enhanced in the size condition in comparison to the luminance condition. Furthermore, within the size condition grasping had a more enhanced positivity than pointing.

The enhanced positivity for the size condition compared to the luminance condition may solely reflect the fact that it was easier to determine if the circles were the same size, than it was to determine if they were the same luminance. A modulation of the P1 component with grasping having a more enhanced positivity relative to pointing in the size condition seems to reflect action-perception congruency effects. This may be evidence that dimensional weighting effects can influence the early sensory P1 component (80–140 ms), in that dimensions which should be processed with priority and are congruent with the task at hand can lead to modification of this early sensory component.

The N1 component was analyzed 160 – 200 ms post-stimulus on the electrodes O1, O2, PO7, PO8, P7, and P8.In the size condition on the different size trials there was a main effect with pointing being more negative than grasping. One may initially want to interpret this as action-perception interference effects, but in the size condition on the different size trials pointing was faster than grasping in RTs, so this ERP effect might be one of pointing overall requiring less cognitive resources than grasping. In this study it is likely that participants may have become over-trained due to all of the practice, therefore causing the planning of pointing to become almost automated and requiring less cognitive resources.

In conclusion, these results seem to show that early sensory process can be influenced by the congruency of an action with a task relevant dimension. However, it is still not clear how late processing, namely discrimination of features, has a role in action-perception interference effects. It may be wise to conduct an EEG study to investigate these effects in a paradigm similar to (Carlson & Wykowska, in review, see Chapter 2).

Enhancing Joint Attention Skills in Autistic Children via a Robot

Chapter 5 addresses how to use knowledge gained in the lab in applied real-world settings. In this experiment a robot named “CuDDler” (A*Star) served to enhance the joint attention (JA) skills of children with Autism Spectrum Disorder (ASD). Within JA there are two mechanisms. One which functions to initiate joint attention (IJA); e.g., showing an object to others; and one which functions to respond to joint attention (RJA); e.g., turning one's head to look in the direction that another person is pointing and looking (Mundy & Crowson, 1997). The idea was that by following the robot’s gaze cuing the children’s JA skills would improve. Two groups of children with ASD were tested, one group received robot treatment and the other group served as a control group. Both groups’ JA skills were tested pre and post experimental sessions (robot treatment or control sessions) with the abridged Early Social Communications Scale, ESCS (Mundy, Delgado, Block, Venezia, Hogan, & Seibert, 2003).

Robot treatment consisted of a training session to familiarize the children with the task, and then 8 sessions of approximately 10 minutes were conducted over a period of 4 weeks (2 sessions per week). Children in the control condition received an equal amount of sessions, but they played with a teddy bear or other toys during this time instead of interacting with the robot. In the robot treatment sessions the robot “looked” at one of two pictures simultaneously presented on two phone screens placed left and right of the robot. The task of the child was to verbally report the color of the picture the robot was “looking” at.

The scoring system for the ESCS (Mundy et al., 2003) was used by the experimenter and also an independent coder who was naive to the experiment. Intraclass correlations coefficients were calculated between the scores of the two raters. These results showed that the scores correlated highly and therefore, the scores were averaged together before being submitted to statistical tests. Scores of the two types of JA (IJA and RJA) were analyzed separately.

Results showed that the groups were not significantly different on their pre-test scores nor post-test scores on either IJA or RJA. The robot treatment group’s scores for both IJA and RJA significantly improved from pre-test to post-test; while the control groups did not. As the treatment and control did not differ significantly on post-test scores the data were look at further, suggesting that although the groups were not significantly different on their pre-tests scores that the treatment group contained two children with more sever ASD. It seems that these children may have driven the increase in scores from pre- to post-test. These results show that robot therapy can be used to improve the JA skills of children with ASD and may be most beneficial for those children in the mild-moderate to moderate-sever range of the spectrum.

Conclusions

The first three studies (Chapters 2, 3, 4) presented in this dissertation were conducted to investigate the reason why in some studies action-perception links result in impairment effects and in other studies result in facilitation effects. Furthermore, how these impairment effects come about with real-world action plans was investigated. The final study (Chapter 5) moves from the lab to the real-world setting of teaching children with Autism Spectrum Disorder (ASD) joint attention skills via a robot.

Results of Chapter 2 replicate the prior work by showing that planning of real-world actions can facilitate the detection of a target which shares dimensional properties with the action to be performed (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012). Namely, size was considered a relevant dimension for grasping movements since, specification of size-related parameters is necessary to control grip aperture (Jeannerod, 1984; Milner & Goodale, 1995; Tucker & Ellis, 2001). Whereas, luminance was considered a relevant dimension for pointing movements because, during pointing movements luminance enables efficient localization of an object (Anderson & Yamagishi, 2000; Gegenfurtner, 2004; Graves, 1996).

Furthermore, Chapter 2 uses real-world action planning with a paradigm similar to Müsseler and Hommel (1997 a, b) in that a discrimination task performed on features of a target was used. This showed that when processing is required at the feature-level interference effects might be observed. Therefore, it seems that perhaps the reason why some studies find facilitation effects and others find impairments effects is due to the level at which perceptual processing is required, be it at the dimensional level or the feature level.

Results of Chapter 3 show that action-perception interference effects due to discrimination of features can be found not only in an attentional task (Carlson & Wykowska, in review, see Chapter 2), but also for a lower-level perceptual task which does not require attentional selection. Finally, Chapter 4, using the paradigm of Chapter 3, showed with ERP methodology that action-perception congruency (facilitation) effects related to dimensional processing may occur during early sensory processing (such as the time frame of the P1 component). However, it is not clear if action-perception interference (impairment) effects related to feature processing may occur during later processing (such as the time frame of the N1 component).

The final study (Chapter 5) moves from the lab to an applied setting where it was shown that a robot named “CuDDler” (A*Star) can be used as a tool to improve the joint attention skills (both initiating and responding to joint attention) of children with Autism Spectrum Disorder (ASD).

In summary, these chapters suggest that both intentional weighting and feature binding might occur during action planning and that action-perception congruency or interference effects are dependent on which level of perceptual processing is required (at the level of dimensions or features). It is suggested that processing at the level of dimensions can be done through the intentional weighting mechanism, which leads to congruency effects. While processing at the level of features might activate feature binding which leads to interference effects. Finally, it is seen how knowledge acquired in the lab about cognitive psychology can be applied in real-world settings; here the improvement of joint attention skills of children with ASD).

Chapter 1

General Introduction

Bi-directionality of Action-Intentions and Perceptual Processes

In the past twenty years or so, evidence has begun to emerge which suggests that there is a bi-directional link between perception and action (Bekkering & Neggers (2002); Craighero, Fadiga, Rizzolatti & Umiltà (1999); Fagioli, Hommel & Schubotz (2007); Müsseler & Hommel (1997); Wykowska, Schubö & Hommel (2009); Wykowska, Hommel & Schubö (2012). The Common Coding Approach (Prinz, 1997) and The Theory of Event Coding (Hommel, Müsseler, Aschersleben, & Prinz, 2001) suggest that perceived events and planned actions share a common representational domain, therefore allowing for this bi-directional link.

For the intentions of this thesis certain stages of action and perception will be addressed. This thesis will discuss action based on Woodworth's Two-Component Model for goal-directed aiming. This model suggests that there is an initial stage (which is rapid and stereotyped) being referred to as the **planning component** and a later stage (which is slower and characterized by discontinuities in the time-displacement profile) referred to as the **online control component** (Woodworth, 1899; Elliott, Helsen, & Chua, 2001).

This thesis will discuss perception based on Feature Integration Theory (FIT) purposed by Treisman & Gelade (1980). FIT proposed two stages of visual processing, the first being a **pre-attentive stage** with a parallel processing system which requires little attention and is effective at **detection** of the absence or presence of a target which is defined by only one **dimension** (ex. color, shape, orientation)[1.1]. The second stage is **attentive** and operates via a serial processing system. This system is required when **discriminating** between objects that are defined by a combination of **features**.

[1.1] Note that Treisman & Gelade (1980) refer to these characteristics as features, but the author of this thesis will refer to them as dimensions.

Individual Stages of Action and Perception

Stages of Action

To better understand how action and perception can be linked it is beneficial to first look at the two processes and their proposed stages separately. In 1899 Woodworth conducted research on actions performed towards targets (drawing a line to a target with a pencil on paper). This research lead to the observation that the initial stages of an aiming movement are relatively rapid and stereotyped; while the later stage of the movement (approaching the target) are slower and characterized by discontinuities in the time-displacement profile. In this seminal work, Woodworth (1899) suggested that aiming movements are composed of an initial impulse phase and a later control phase. Woodworth's Two-Component Model for goal-directed aiming has persisted in many theories of motor cognition. With the initial stage (which is rapid and stereotyped) being referred to as the planning component and the later stage (which is slower and characterized by discontinuities in the time-displacement profile) being referred to as the online control component (see Elliott, Helsen, & Chua, 2001, for a review).

Stages of Perception

The role of perception in visual search has been addressed in the seminal work of Treisman & Gelade (1980). In this work the Feature Integration Theory (FIT) was proposed. FIT proposed two stages of visual processing, the first being a pre-attentive stage with a parallel processing system. This stage is effective when visual search requires the detection of the absence or presence of a target which is defined by only one feature (ex. color, shape, orientation)[1.1]. This stage requires little attention and usually exhibits fast reaction times. The second stage is attentive and operates via a serial processing system. This system is required when discriminating between objects that are defined by a combination of features. This second stage requires conscious focal attention and is slower than the pre-attentive stage.

This has been supported by Sagi & Julesz (1985) who found that detecting and counting orientation targets can be done in the parallel pre-attentive stage; while determining the orientation (a feature) of a target requires serial search with focal attention.

Kumada (2001) has also addressed the issue of dimensions and features. One of his experiments included a simple visual search task; while another included a compound search task. In Experiment 1A a simple visual search task was used wherein one target item was present among nine distractor items. The distractor items were all rectangles of the same size with an arrowhead inside of them either pointing left or right. The target could either be of different orientation, size, or color than the distractors. Sometimes the target was defined block-wise by dimension (orientation, size, or color) other times it was not. Reaction times were faster when the relevant target dimension was predefined as compared to when it was not.

In Experiment 1B the same stimuli were used under a compound search task, in which participants responded to a feature, left or right pointing arrowhead, of the target within its defining dimension. Once again, sometimes the target was defined block-wise by dimension and other times it was not. However, in this experiment there was no significant difference in reaction times between when the relevant target dimension was predefined and when it was not. Therefore, it was shown that when focal attention to targets was required there was no longer a benefit of knowing the dimension of the target beforehand. This suggests that feature based modulation is limited as a source for controlling spatial attention.

Action-Perception: Facilitation Effects or Impairment Effects?

Now that the stages of action and perception which are of interest for this thesis have been addressed separately it can be discussed how these systems might work together. As stated previously many studies have investigated the fact that action and perception actually interact in a bi-directional manner. However, in investigating these bi-directional action-perception links it has been found that actions can in some circumstances **impair** the perception of action-congruent stimuli (Müsseler and Hommel, 1997 a, b); while in other circumstances, actions can **facilitate** the perception of action-congruent stimuli (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö, 2012; Wykowska & Schubö 2012).

Interference (Impairment) Effects

In the studies of Müsseler & Hommel (1997 a, b) a standard paradigm was used (see Figure 1.1), this paradigm consisted of the presentation of a right or left pointing arrow which indicated if the participant should later press the right or left key, participants then performed a double key press which activated the presentation of a masked right or left pointing arrow, directly after this participants were required to execute their planned keypress quickly (according to the beginning cue stimuli), finally after 1008 ms participants gave an unspeeded judgement of the masked arrow. Results show that identification of the masked arrow was reduced when the to-be-executed action (planned keypress) was compatible with the masked arrow. For instance when a right keypress was planned (according to a right-pointing arrow cue) and a masked right-pointing arrow was presented later discrimination of the masked arrow was impaired. As can be seen from these studies feature overlap between a prepared manual response and a target leads to action-perception interference effects (impairment).

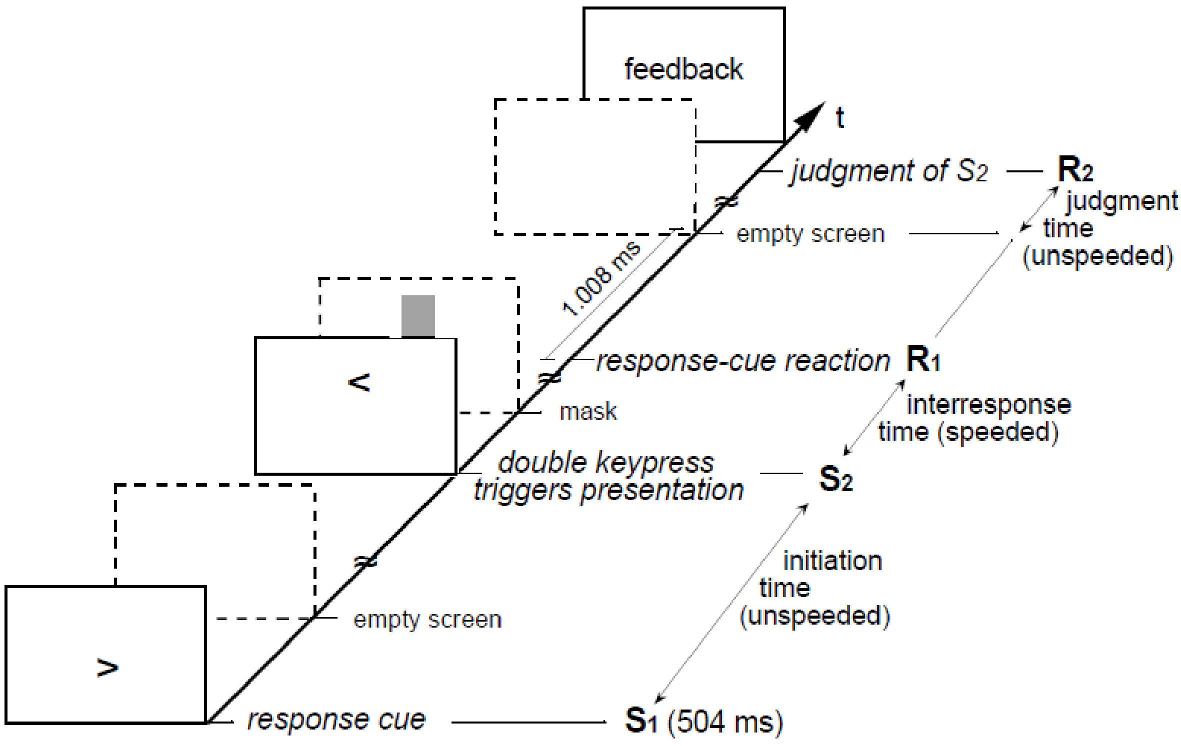


Figure 1.1: Standard paradigm in studies of Müsseler & Hommel (1997 a, b). Participants are cued which key to press later (S1), after a double keypress they are then presented with a masked-arrow which they must identify later (S2). After S2 they must make their cued response (R1) and finally they identify the masked-arrow (R2). Figure taken from Müsseler & Hommel (1997 b) with permissions.

Facilitation Effects

In the studies of Wykowska, Schubö, & Hommel (2009), Wykowska, Hommel, & Schubö (2011), Wykowska, Hommel, & Schubö (2012), and Wykowska & Schubö (2012) dimensional overlap between a prepared manual response and a pop-out target was investigated. This was done by considering size a relevant dimension for grasping movements since, specification of size-related parameters is necessary to control grip aperture (Jeannerod, 1984; Milner & Goodale, 1995; Tucker & Ellis, 2001). Whereas, luminance was considered a relevant dimension for pointing movements because, during pointing movements luminance enables efficient localization of an object (Anderson & Yamagishi, 2000; Gegenfurtner, 2004; Graves, 1996). Hence, it was expected in the studies Wykowska and colleagues that preparation of a grasping movement would facilitate detection of size targets and preparation of a pointing movement would facilitate detection of luminance targets.

For the studies of Wykowska and colleagues a standard paradigm was used (see Figure 1.2), this paradigm consisted of the presentation of a cue picture, a left hand performing either a grasping or pointing movement to a cup; this indicated if the participant should prepare a grasping or pointing movement to be executed later, after this a search display was presented and participants were required to detect the target among an array of items. Participants were informed block-wise if the target would be defined by luminance or size. Directly after the search display the participants were given unlimited time to detect if the target was present or not. After this search task a yellow asterisk appeared above one of three paper cups to indicate which cup the prior cued/ prepared action should be made towards. Results from this study showed that preparation of a grasping movement facilitated detection of the size target and preparation of a pointing movement facilitated detection of a luminance target.

Wykowska & Schubö (2012) expanded on this by using the same paradigm in conjunction with Electroencephalography (EEG). Results of this study showed modulation of the P1 component in the time window of 70–130 ms post-stimulus at electrodes O1, O2, PO7, and PO8 in the luminance condition, but not the size condition. Within the luminance condition there was an enhanced positivity of the P1 component when participants had prepared a pointing movement relative to when they had prepared a grasping movement. Additionally, when comparing contralateral and ipsilateral waveforms a modulation of the N2pc component in the time window of 230–300 ms post-stimulus at electrodes PO7 and PO8 was found in the size condition, but not the luminance condition. Within the size condition there was an enhanced negativity of the N2pc component when participants had prepared a grasping movement relative to when they had prepared a pointing movement. As can be seen from these studies when a prepared manual response has open parameters which fit the dimensions of a target stimulus action-perception congruency effects (facilitation) can be found both behaviorally with RTs and also neurophysicalogically with early perceptual processing and attention mechanisms being modulated.

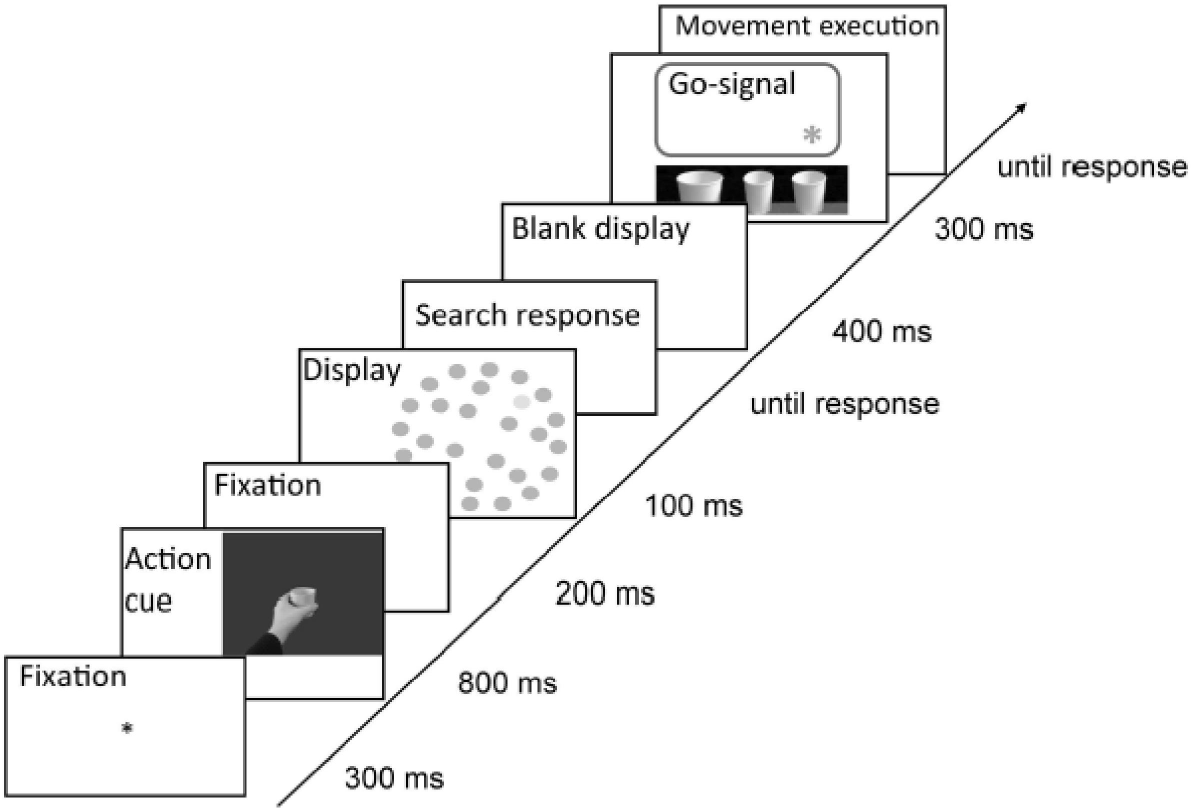


Figure 1.2: Standard paradigm of Wykowska and colleagues. Participants are cued to prepare either a grasping or pointing movement, then they are presented with a search task for either a luminance or size target (dimension defined block-wise), after the search task they respond if the target was present or absent, and finally they execute their prepared movement (grasp or point) to one of three cups (indicated by an asterisk). Figure taken from Wykowska, Hommel, & Schubö (2012) open-access article (Creative Commons Law).

Intermediate Summary

When the stages of action and perception are looked at separately it can be seen that both process have two stages. For action, Woodworth's Two-Component Model for goal-directed aiming suggests there is an initial stage (which is rapid and stereotyped) being referred to as the **planning component** and a later stage (which is slower and characterized by discontinuities in the time-displacement profile) referred to as the **online control component** (Woodworth, 1899; Elliott, Helsen, & Chua, 2001).

For perception, Treisman & Gelade (1980) purposed the Feature Integration Theory (FIT). FIT proposed two stages of visual processing, the first being a **pre-attentive stage** with a parallel processing system which requires little attention and is effective at **detection** of the absence or presence of a target which is defined by only one **dimension** (ex. color, shape, orientation). The second stage is **attentive** and operates via a serial processing system. This system is required when **discriminating** between objects that are defined by a combination of **features**.

Importantly, in the past years evidence has come to light to support the idea that action and perception are in fact bi-directionally linked and can influence each other. However, investigation into these links has led to, in some circumstances action **impairing** the perception of action-congruent stimuli (Müsseler and Hommel, 1997 a, b) and in other circumstances action **facilitating** the perception of action-congruent stimuli (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö, 2012; Wykowska & Schubö, 2012). When these studies are looked at closer it seems possible that **feature** overlap between a prepared manual response and a target leads to action-perception **interference effects (impairment)**; whereas, **dimension** overlap between a prepared manual response and a target leads to action-perception **congruency effects (facilitation)**.

Intentional Weighting Mechanism

The Intentional Weighting Mechanism (IWM) accounts for facilitation effects (Hommel et al., 2001; Wykowska et al., 2009; Memelink & Hommel, 2013). The IWM begins with the assumptions that actively produced events and perceived events are linked between cognitively represented common codes which hold the sensory-components of the two processes. These common codes are thought to be formed during action-planning and to consist of episodic memory traces or **event files** (Hommel, 2004).A concept similar to event files has also been proposed by Wolfe & Bennett (1997) who expanded on the ideas of Kahneman & Treisman (1984). Wolfe & Bennett (1997) discuss pre-attentive “object files” which consist of shapeless bundles of basic features, suggesting that pre-attentively one can be aware of the features of an object, but to recognize an object requires attention.

Within the IWM it is then suggested that event files consist of intention- or goal-related dimensions being given a weight which is adjusted based on the task and stimuli at hand. Furthermore, the weighting of these intention- or goal-related dimensions also activates and leads to weighting of features of the dimensions (see Figure 1.3). These ideas are in-line with those of Found & Müller (1996) who proposed the Dimension-Weighting account (DWA). DWA consist of a master-map where in different stimuli dimensions are given a weight based on saliency signals. If the target dimension is known in advance, signals from that dimension are increased. However, if the target’s dimension is not known beforehand weight shifts from non-targets to the target dimension.

Furthermore, the IWM much like Woodworth’s Two-Component Model Hommel (2010) also proposes two stages of action. The first being an “offline” action planning processes which makes use of invariant characteristics of an action stored in memory. The second being an “online” action adjustment process which is needed for filling open parameters of action planning. It is thought that this second process, “online” action adjustment, can be influenced by perceptual processing as it delivers the information needed to fill open parameters of action adjustment. That is to say action-intention should bias perceptual systems to focus on those perceptual dimensions that are likely to provide control-relevant information. For example, when planning a grasping action to a cup, perception needs to fill information about the *specific* size (dimension) of the cup. The logic of the IWM is that it prioritizes processing of the dimension that could potentially be relevant for online adjustments of prepared actions (see Figure 1.3).

The IWM shows how preparing an action can cause action-relevant perceptual dimensions to become more salient and hence increase detection of stimuli with the relevant dimension. This may explain the facilitation effects seen by (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö, 2012; Wykowska & Schubö, 2012), but it does not explain the interference effects seen by (Müsseler and Hommel, 1997 a, b).

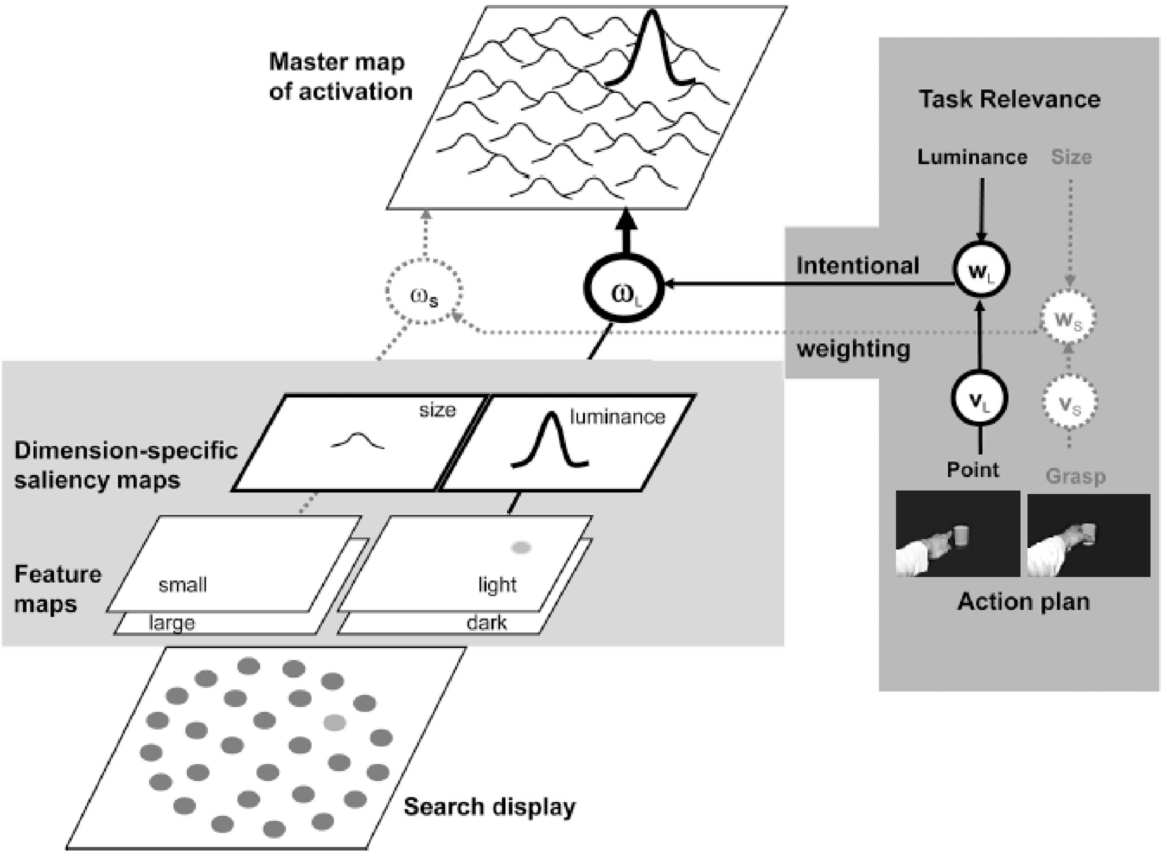


Figure 1.3: The Intentional Weighting Mechanism (IWM). Here it is shown that when the task relevant dimension is luminance and a pointing action is planned (grey box on the left) that weights are given to this dimension (WL) and action (VL), these weights are then summed together in an event file (ωL). This weighting leads to the target which is defined on the relevant dimension (here luminance) having a higher weight and therefore leading to faster detection than if a grasping movement had been prepared (grasping is considered incompatible with the luminance dimension). Figure taken from Wykowska, Schubö, & Hommel, 2009 and adapted with permission.

Cognitive Neuroscience in Applied Domains: Autism

Thus far paradigms, concepts, and mechanisms of cognitive neuroscience have been discussed, but one of the most important aspects of gathering such information is then to be able to apply it outside the experimental domain in real world situations. So far the linking of action and perception has been discussed, but this was in a contained system (an individual person), however, often in real world situations a person is not only interacting with the environment, but also other people in the environment. Such social interactions require social skills and the ability to understand information presented by others and the ability to convey information to others.

Simulation Theory (ST) attempts to explain how a person makes sense of the mental states and actions of others in everyday situations. ST suggests that a person (observer) simulates the mental states and actions of another person as if doing those things one's self, this is known as mental simulation. This perceiving of another's mental states and actions as if they are the observer's own allows the observer to predict and adapt to the mental states and actions of the observed person (Gordon & Cruz, 2002).

The mirror neuron system (MNS) is a likely candidate for bridging between the self and the actions of others. The MNS consist of regions in the premotor cortex, the supplementary motor area, the primary somatosensory cortex and the inferior parietal cortex (Molenberghs, Cunnington, and Mattingley, 2009). These regions tend to become active both when a person acts on their own or observes another person performing actions (Rizzolatti & Craighero, 2004). For instance, Uddin, Iacoboni, Lange, and Keenan (2007) and Keysers & Gazzola (2007) have found that the same areas of the brain fire when an individual views others performing physical actions such as grasping or tearing.

It can be seen that action and perception are not only linked in an individual's brain, but that these systems are often also activated within an individual when observing or interacting with others in the environment. One way of interacting with the environment and others is by using the social skill of joint attention (JA). Joint attention is the sharing of attention between a person, another person, and an object or event (Charman, 2003; Leekam, López, & Moore, 2000). It has been suggested that there are two separate mechanisms for joint attention. One mechanism functions to initiate joint attention (IJA); e.g., showing an object to others; the other mechanism functions to respond to joint attention (RJA); e.g., turning one's head to look in the direction that another person is pointing and looking (Mundy & Crowson, 1997). Joint attention seems to be a pivotal skill since it begins to develop between around 6 to 12 months of age (Charman, 2003; Moore & Dunham, 2014). In fact, it is even thought that this skill may help in the development of other skills, such as language acquisition (Meindl & Cannella-Malone, 2011).

However, in some children these skills do not develop properly leading to dysfunction in multiple areas of everyday life. One group of children who tend not to develop these skills properly are those with Autism Spectrum Disorder (ASD). ASD is described by the DSM-5 as a range of disorders characterized by social deficits and communication difficulties, stereotyped or repetitive behaviors and interests, sensory issues, and in some cases, delayed cognitive development (American Psychiatric Association, 2013). A diagnosis of ASD can encompass several disorders such as autism, Asperger's syndrome, childhood disintegrative disorder and pervasive developmental disorder not otherwise specified; these disorders were previously considered separately. Therefore, the term *spectrum* refers to the wide range of symptoms and severity present within this diagnosis. It still remains though that children diagnosed with ASD tend to be impaired in their abilities to communicate and interact with others.

Fortunately, early intervention and therapy seems to be able to improve language, communication, and social skills for some children with ASD (Meindl & Cannella-Malone, 2011; Mundy, Sigman, & Kasari, 1990; Whalen & Schreibman, 2003). Since joint attention is a skill which is developed early on and since deficits in this ability can potentially lead to deficits in communication and other social skills JA is a vital skill to target for early intervention and therapy. In the past years a new type of intervention has started to emerge for children with ASD. This intervention is that of social robotics (Cabibihan, Javed, Ang, & Aljunied, 2013; Dautenhahn, 2003; Scassellati, Admoni, & Matarić, 2012). It is thought that children with ASD may benefit more from interactions with a robot than a human, since a robot's behavior is predictable, it has a standardized voice, and few facial expressions; whereas human therapists may show variability in behavior, voice, and facial expressions. The predictableness and lack of features that a robot has compared to a human therapist may make it easier for a child with ASD to process and interpret a robot's behavior and minimalistic expressions.

Chapter 2

The Intentional Weighting Mechanism: Perceptual Dimensions versus Features

Abstract

The Theory of Event Coding (TEC) proposes that action and perception are linked through a common representational system, which allows for bidirectional influences. TEC predictions have been investigated with multiple studies; some of them showed action-perception congruency effects (Wykowska et al., 2009) while others revealed action-perception interference effects (Müsseler & Hommel, 1997a). Therefore, the direction of action-perception effects is variable across paradigms. The aim of the present study was to use a modified version of experimental paradigm of Wykowska et al. (2009) and target at both types of effects, depending on the type of perceptual task (detection vs. discrimination) and thus the level of perceptual processing (perceptual features vs. dimensions). In the experimental paradigm, participants were asked to either detect the presence of a size target in a visual search display or to discriminate if a size target was large or small. Action-related congruency effects were observed in the detection task while interference effects were found in the discrimination task. This pattern of results explains why action-perception congruency effects are found in some paradigms while in other paradigms, preparing an action interferes with a perceptual task.

Introduction

The Theory of Event Coding (TEC) proposed by Hommel, Müsseler, Aschersleben, & Prinz (2001) suggests that a common representational medium codes stimulus representations underlying perception and action representations underlying action planning. This would mean that action and perception are activated through a linked representational system, which allows for bidirectional influences. TEC predictions have been investigated with multiple paradigms; some of them showed action-perception congruency effects: typically, when an action is prepared while a perceptual task is being performed stimulus dimensions congruent with the planned action are processed with priority, relative to dimensions that are action-incongruent (Fagioli, Hommel, Schubotz (2007); Wykowska, Schubö, Hommel (2009); Wykowska, Hommel, Schubö (2011); Wykowska, Hommel, Schubö (2012); Wykowska & Schubö (2012); Hommel, (2010); Memelink and Hommel (2013). Other paradigms showed action-perception interference effects (Müsseler and Hommel, 1997a,b): identification or detection of a stimulus which shares perceptual features with features of an executed manual response is impaired.

To date, it has not been clarified why direction of action-perception effects is variable across paradigms. We propose that the direction in which action-perception biases are observed (congruency or interference effects) is related to the stage of processing both in perception and in action planning. Regarding action, Woodworth's Two-Component Model for goal-directed aiming (Woodworth, 1899) proposes an initial stage (which is rapid and stereotyped), referred to as the *planning* component and a later stage (which is slower) being referred to as the online control component (see Elliott, Helsen, & Chua, 2001, for a review). Similarly, Hommel (2010) proposes that action control consists in an "offline" action planning processes and "online" action adjustment. While "offline" action planning makes use of invariant characteristics of an action stored in memory, the "online" action adjustment is needed for filling open parameters of action planning. It is the latter process for which perceptual processing delivers information in a fast and efficient manner about how the open parameters should be filled. That is, for example, for planning a grasping action, perception needs to fill information about *specific* size of an object to be grasped. Hence, Hommel (2010) as well as Wykowska et al. (2012) propose the *intentional weighing* mechanism that biases processing of perceptual *dimensions* (e.g., size, shape, color) that can potentially be relevant for an action plan. This means that action-relevant dimensions get processed with priority over other dimensions (and this is observed in the form of action-perception congruency effects, as in Fagioli et al., 2007 or Wykowska et al., 2009)[1]. At the same time, however, if action planning contains already specified feature values (e.g., *small* object for grasping), interference between action planning and perceptual processing might be observed, due to that individual features might be occupied by an action plan (through action-perception feature binding), and thus not easily available for perception – an idea inherent in the concept of event files of Theory of Event Coding (TEC) by Hommel et al. (2001). Both intentional weighting and feature binding might occur during action planning. However, here we propose that dependent on what level of processing is targeted by the task, either intentional weighting in the form of congruency effects or feature binding in the form of interference effects might be observed. This reasoning is based on the observation that studies which report interference effects are different from those reporting congruency effects in one crucial characteristic: While the former target at individual features (e.g., discrimination of left/right direction of an arrow while preparing a left/right manual response, as in the case of Müsseler & Hommel, 1997b), the latter address – through design

[1] The concept of intentional weighting is in line with an account of dimensional weighting (Found & Müller, 1996; Müller et al., 2009) which postulates that top-down biases operate at the level of processing dimensions, over and above processing of individual features.

– perceptual dimensions (e.g., detection of size targets in a visual search task, as in Wykowska et al., 2009).

Aim of Study

The aim of the present study was to use a modified version of paradigm sequence of Wykowska, et al. (2009) to test this line of reasoning. That is, to examine if congruency or interference effects would be observed, depending on whether the task required processing at the level of dimension- or feature maps (Treisman & Gelade, 1980; Found & Müller, 1996).

Specifically, in the studies of Wykowska et al. (2009) participants were asked to prepare a pointing or a grasping movement (this was signaled through presentation of a picture cue depicting a hand grasping or pointing to an object). While participants were preparing the movement, but prior to its execution, they were asked to perform a perceptual task: detection of either a size or a luminance pop-out target in a visual search display. The visual search stimuli were presented on a computer screen while the objects that were to be grasped or pointed to were placed below the screen. The authors found that preparation of a grasping movement facilitated detection of size targets; while preparation of a pointing movement facilitated detection of luminance targets. This was interpreted to be due to size being a relevant *dimension* for grasping (when grasping, size of the to-be-grasped item needs to be specified for appropriate grip aperture) while luminance was interpreted to be a relevant *dimension* for pointing (luminance is tightly linked to localizing and the function of a pointing gesture is to localize events in the environment). The detection task in the study of Wykowska et al. (2009) and its subsequent follow-up studies (Wykowska et al., 2011, 2012; Wykowska & Schubö, 2012) required processing only at the level of dimensional maps and thus the *intentional weighting* mechanism was observed in the form of congruency effects (and not interference).

In the present study, we aimed at introducing the necessity of processing at the level of perceptual features through supplementing the detection task by a discrimination task. Participants took part in two experiments on separate days. On the first day they performed a detection task with the paradigm being similar to that of Wykowska, et al (2009). Participants were to detect a size pop-out target (required response was present/absent, independent of whether it was smaller or larger than the other items in the visual search display). We reasoned that standard congruency effects should be observed, that is faster reaction times when participants were simultaneously preparing for grasping, relative to pointing. On the second day they performed a discrimination task, participants had to discriminate the features of a target, which was already defined on its dimension. It was thought that in this paradigm interference effects would be observed, because biasing individual features in order to deliver information for open parameters of an action plan would not be beneficial. More specifically, we reasoned that when participants were aware that they would be discriminating if the target was large or small, they would have slower RTs during preparation of a grasping movement, relative to preparation of a pointing movement (interference effects).

Methods

Participants

Twenty-one paid volunteers (8 men) aged from 20 to 31 years (M age: 24) took part. Two participants were excluded from analyses; one due to technical issues and the other due to high error rates (> 3SD of the entire sample) in both search and movement tasks. All participants were right-handed and all had normal or corrected-to-normal vision. The experiment was conducted with the understanding and written consent of each participant.

Stimuli and Apparatus

Stimuli were presented on a 17'' CRT screen (85 Hz refresh rate) placed at a distance of 85 cm from the participant. Stimulus presentation was controlled by E–Prime software (Psychology Software Tools, Pittsburgh, PA, USA). Cues specifying what type of action to prepare (i.e., grasping or pointing) consisted of photographs of a left hand performing a pointing or a grasping movement on a white paper cup. The photographs were black and white covering 12.5° x 18.4° of visual angle. As the participant prepared the movement, a search display was presented. The display contained 28 items (gray circles, 1.5° in diameter; 22 cd/m² of luminance) positioned on three imaginary circles with a diameter of 4.2°, 9.9°, and 15.3°, respectively.

In the detection task (see Figure 2.1) the display could either contain no target, all circles the same (1.5° in diameter; 22 cd/m² of luminance) or one target could be present. The target could either be smaller or larger than the other circles in the array. The smaller target circle had a diameter of 1.3° and luminance of 22 cd/m². The larger target circle had a diameter of 1.8° and luminance of 22 cd/m². Small and large circles had an equal probability of appearing. Participants were required to respond with one mouse key when the target (small or large) was present and the other mouse key when the target was absent (response mapping was counterbalanced across participants).

In the discrimination task (see Figure 2.1) the display always contained one target. The target could either be smaller or larger than the other circles in the array. As in the detection task, the smaller target circle had a diameter of 1.3° and luminance of 22 cd/m² while the larger target circle had a diameter of 1.8° and luminance of 22 cd/m². Small and large circles had an equal probability of appearing. Participants were required to respond with one mouse key when the target was small and the other mouse key when the target was large (again response mapping was counterbalanced across participants).

After completion of the visual search task (but still within the same experimental trial) participants were asked to make a grasping or pointing action to one of three paper cups. The cups were arranged 80 cm in front of the observers below the computer screen. A large dark gray (0.43cd/m²) cup, 8 cm (4.5°) in diameter was placed on the left, a middle gray (1.8 cd/m²) cup, 6.5cm (3.7°) in diameter in the middle, and a small white (3cd/m²) cup, 5cm (2.8°) in diameter on the right.

Procedure

All participants took part in three sessions, one practice session and two experimental sessions. There was a minimum of one and a maximum of two days between the practice session and the first experimental session (detection task). The second experimental session (discrimination task) was performed the day after the first experimental session. The discrimination task was always performed after the detection task, so that participants would not use the feature-detection mode that they might have acquired in the discrimination task.

In the practice session participants practiced only the movement task in order to be able to perform the combined movement and perceptual task later during the experimental session. In the practice session, participants performed four blocks of one movement type only (pointing or grasping, 18 trials per block) and two blocks of both types of movement randomly intermixed (54 trials per block). They were instructed to place their left hand on the spacebar all the time unless they were making a movement. At the beginning of each trial a black fixation asterisk was presented for 300 ms, then the movement cue was presented for 800 ms (a picture of a left hand either pointing or grasping). After this, a fixation asterisk was presented for 200 ms. Then a blank screen (to provide some inter-stimulus interval) was presented for 500 ms. Then a yellow asterisk was presented above one of three paper cups below the monitor. Once the yellow asterisk appeared, the participant released the spacebar and used their left hand to make the planned movement to the indicated cup. As soon as they released the spacebar the yellow asterisk disappeared from the screen. Upon completion of a movement (grasping or pointing towards one of the cups), an experimenter seated in a separate room and observing the participants through a camera registered the movement type with a mouse key (left key for grasping vs. right key for pointing). Participants completed their movement by returning their hand to the space bar and this generated presentation of a blank screen for 300 ms, which served as an inter-trial interval. Participants were instructed to stress accuracy over speed when reaching for the cups. Also, they were instructed that when grasping the cup they should place all 5 fingers around the cup and when they were pointing to the cup to actually lift their arm and point; and not touch the cup.

During the experimental sessions proper (see Figure 2.1), participants performed a short warm-up block (18 randomized trials) in which they practiced the movements only, identical to the practice session. After the movement warm-up, participants completed a practice block (containing 36 randomized trials) with both movement and visual search tasks. First, a fixation asterisk was presented for 300 ms, then a movement cue was presented for 800 ms. Next, a fixation asterisk was presented for 200 ms, after which the search display was presented for 100 ms. Then a participant was given unlimited time to respond to the search task with their right hand, speed was stressed, however. Following their response, a blank screen was presented for 400 ms, then a yellow asterisk cue came above one of three cups which were aligned in front of the display monitor. The yellow asterisk remained on the screen until the participant released the spacebar. After making the movement with their left hand and returning to pressing the spacebar a blank screen appeared for 300 ms. After completion of these practice blocks, participants took part in 12 blocks of 54 trials (detection task) and 8 blocks of 54 trials (discrimination task).

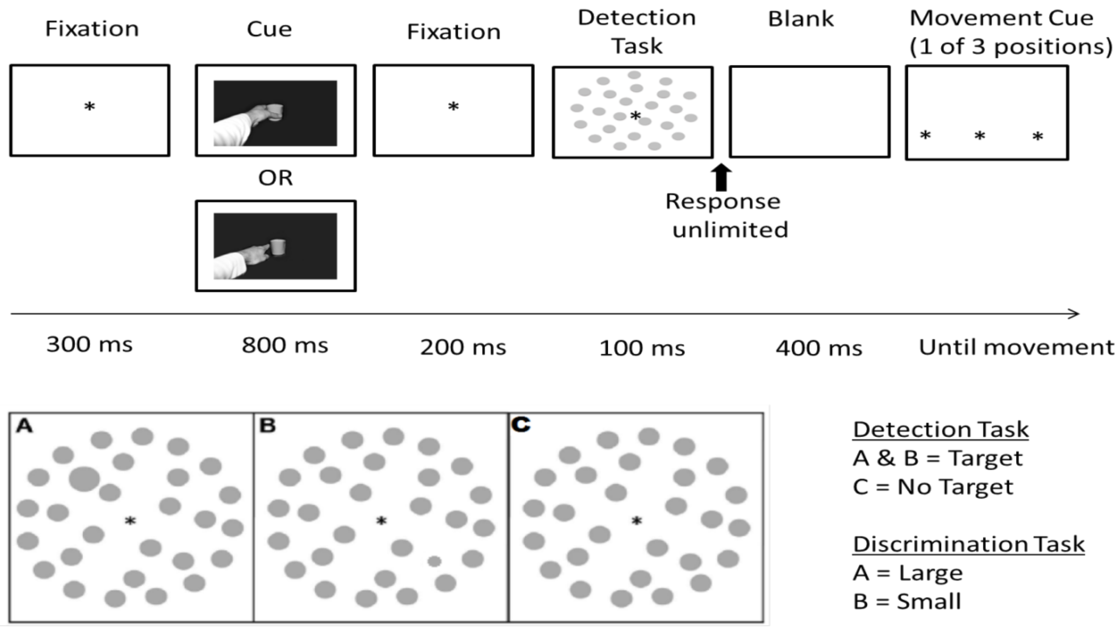


Figure 2.1: A trial sequence (upper). Stimuli types (lower). In the detection task when a large target (A) or a small target (B) was present, participants should respond "target present". When no target was present (C) participants should respond "target absent". In the discrimination task when a larger target (A) was present participants had to respond "target large", when a small target (B) was present they had to respond "target small" (Figure from Carlson, K., & Wykowska, A., in review. *Journal of Cognitive Psychology*, open access).

Data Analysis & Results

Trials with RTs above 1,500 ms were excluded from analysis, and so were erroneous movement and search trials. From the remaining data, a 2 x 2 ANOVA on mean RTs with the within-subject factors: task type (detection vs. discrimination) and movement type (grasp vs. point) was conducted. There was a main effect of task type, $F(1, 18) = 51.89$, $p < 0.001$, $\eta p^2 = 0.74$ with participants being faster in the discrimination task (M = 508.47 ms, SE = 26.25 ms) than the detection task (M = 621.36 ms, SE = 31.50 ms). Most interestingly, there was a significant interaction between task type and movement type (see Figure 2.2), $F(1,18) = 4.84$, $p = 0.041$, $\eta p^2 = 0.21$. Planned comparisons (one-tailed paired-samples t-tests) showed that in the detection task grasping (M = 618 ms, SE = 27 ms) was marginally faster than pointing (M = 618 ms, SE = 27 ms), $t(18) = -1.43$, $p = 0.085$. In the discrimination task, pointing (M = 505 ms. SE = 32 ms) was significantly faster than grasping (M = 512 ms, SE = 32 ms), $t(18) = 1.91$, $p = 0.036$.

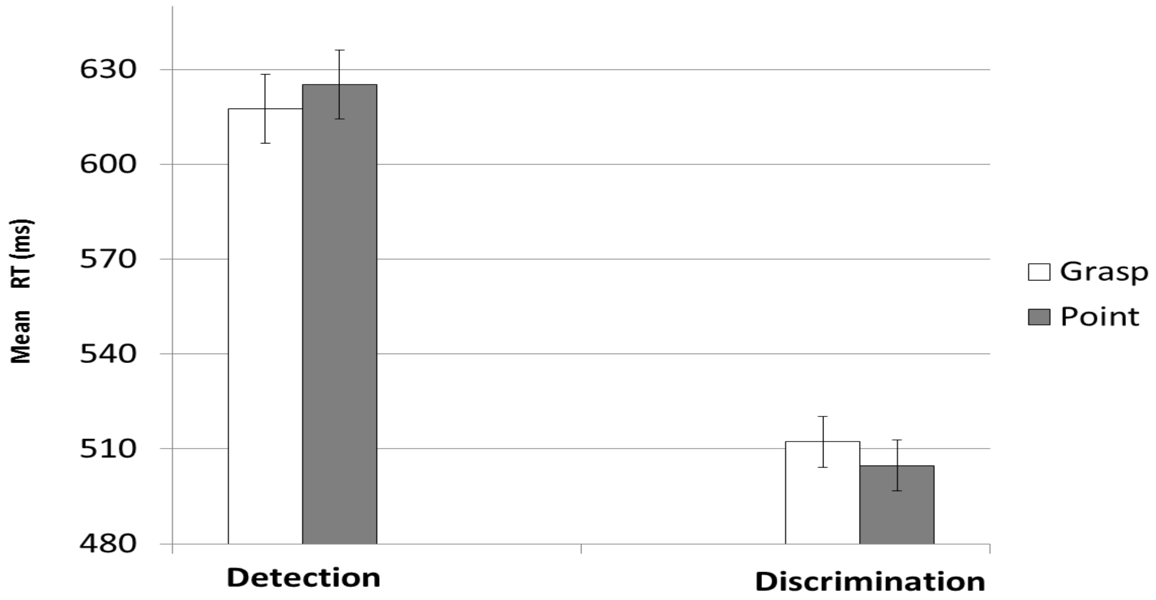


Figure 2.2: Mean reaction times (RTs) for the detection task (left) showing grasping (white bar) to be faster than pointing (gray bar), and for the discrimination task (right) showing grasping (white bar) to be slower than pointing (gray bar). *Error bars* represent within-subjects confidence intervals with 95% probability criterion, calculated according to the procedure described in Cousineau (2005). Figure from Carlson, K., & Wykowska, A., in review. *Journal of Cognitive Psychology*, open access.

Discussion

The aim of this study was to examine whether – dependent on the level of perceptual processing (features vs. dimensions) – action-related congruency or interference effects would be observed. To this aim, we designed a paradigm that was a modified version of the experimental protocol of Wykowska et al. (2009). Participants performed a movement task (grasping or pointing) while simultaneously performing a visual search task – either detecting a size target among distractors (processing at the level of dimensions) or discriminating particular size values of an odd-one-out element of the visual search display (processing at the level of features). Results showed an interaction between task type (detection vs. discrimination) and movement type (grasping vs. pointing). In the detection task, targets were detected faster when participants prepared for a grasping movement (congruent with size), relative to a pointing movement (incongruent with size) – the typical congruency effect. In the discrimination task, however, the pattern was reversed, that is, participants were faster in discriminating size when they prepared for pointing as compared to grasping – a type of interference effect. These results are in line with the hypothesis of this study: when participants process perceptual information at the level of dimensions, congruency effects can be observed, as this is the stage at which intentional weighting operates. In contrast, when feature-level of processing is required, interference effects might be observed due to binding of features in event files across action and perception. Hence, by changing the task from dimension-based to feature-based processing, congruency effects were turned into interference effects. The fact that congruency effects in the target detection task were only marginally significant might be due to that on some trials participants engaged in feature-based processing, even though it was not required by the task. Because the target could be either smaller or larger than the other items, participants might have looked for a “smaller” or a “larger” feature value, thus processing perceptual information at the feature level. This might have attenuated the congruency effects that were more evident in previous studies (Wykowska et al., 2009, 2011, 2012; Wykowska & Schubö, 2012), where target was defined by only one feature within a given dimension. Finally, apart from effects that were of main interest of the study, there was also the main effect of task type with participants being faster in the discrimination task than the detection task. This may simply be due to the fact that the discrimination task was performed on the second day, and therefore the participants had more experience with the task.

In conclusion, the present results suggest that action-related biases of perceptual processing can be observed in the form of congruency effects when the task requires perceptual processing at the level of dimensions or interference effects when feature-based processing is involved. This explains different patterns of results across various paradigms showing action-perception links.

Chapter 3

The Role of Feature Discrimination in Action-Perception Interference Effects

Abstract

The Theory of Event Coding (TEC) proposed by Hommel, Müsseler, Aschersleben, & Prinz (2001) suggests a common representational medium for perception and action planning. Empirical studies have shown two types of effects supporting the "common code" idea: action-perception congruency effects on the one hand (e.g., Fagioli et al., 2007; Wykowska et al., 2009) and interference effects on the other (e.g., Müsseler & Hommel, 1997). This study aimed at examining whether interference effects generalize from simple key presses as in Müsseler & Hommel (1997a,b) to complex and natural actions (as in Wykowska et al., 2009), under the condition that feature-based processing is involved in the task. Participants prepared either a grasping or a pointing movement and then judged if two disks were the same or different either on size or luminance. After the perceptual judgment, participants executed their planned movement to one of three paper cups. Results showed interference effects: congruent action-perception pairs (grasping + size vs. pointing + luminance) resulted in lower sensitivity (as measured by d-prime) in the perceptual task, relative to incongruent pairs (grasping + luminance vs. pointing + size). The present results extend previous findings by showing that action-perception interference effects generalize from simple key presses to complex actions.

Introduction

According to the seminal Theory of Event Coding (Hommel et al., 2001), action and perception are coupled through a common representational medium. Representation of both an action plan and a percept is constituted by a network of features that are temporarily bound together (Hommel, 2004). Various studies have examined links and mutual biases between action and perception. Some of these studies have found action-perception interference effects (Müsseler and Hommel, 1997 a, b): identification or detection of a stimulus was impaired for features that were shared between a stimulus and a prepared action, as compared to conditions in which the features were distinct. Other studies, however, found action-perception congruency effects (Fagioli, Hommel, & Schubotz, 2007; Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö, 2012; Hommel, 2010; Memelink & Hommel, 2013): stimulus *dimensions*[2] congruent with a planned action were processed with priority, relative to dimensions that were action-incongruent. For example, participants were faster to detect size targets when they had prepared a grasping movement; while preparing a pointing movement lead to faster detection of luminance targets (Wykowska et al., 2009; 2011; 2012; Wykowska & Schubö, 2012). Size is considered a relevant dimension for grasping movements because, specification of size-related parameters is necessary to control grip aperture (Jeannerod, 1984; Milner & Goodale, 1995; Tucker & Ellis, 2001). Whereas, luminance enables efficient localization of an object during pointing movements and therefore is considered a relevant

[2] Stimulus dimensions are, for example, color, shape or size. According to Treisman and Gormican (1988), dimension is a set of mutually exclusive values for stimulus attributes. The values are exclusive because a stimulus cannot have two values within the same dimension (e.g, a shape cannot be a circle and a square simultaneously). According to the Dimensional Weighting Account (Found & Müller, 1996), stimuli are processed in the form of saliency signals across various dimension maps. The dimension-specific signals can be weighted in a top-down manner.

dimension for pointing (Anderson & Yamagishi, 2000; Gegenfurtner, 2004; Graves, 1996), Similar congruency effects were found by Fagioli et al. (2007) where preparing a grasping movement facilitated detection of size oddballs, whereas preparing a pointing movement facilitated detection of location oddballs.

Carlson and Wykowska (in review) used a similar paradigm to Wykowska et al. (2009), but with the following modification: additionally to a target detection task in a visual search protocol, participants performed also a discrimination task. Congruency effects were found in the detection task, replicating the previous results (Wykowska et al., 2009; 2011; 2012 as well as Wykowska & Schubö, 2012) while interference effects were observed in the feature discrimination task. This pattern of results was interpreted as supporting the idea that dependent on the level of perceptual processing (feature vs. dimension maps), either congruency or interference effects are observed. It was proposed that the mechanism that underlies congruency effects (the intentional weighting mechanism) operates at the level of dimensional maps while the interference effects are due to binding of individual features into event files. This is based on the reasoning that for open parameters of online action adjustment (Hommel, 2010), the perceptual system needs to deliver information to the action control system in an efficient manner, meaning that perceptual dimensions that can potentially be relevant for a given planned action need to be processed with priority. Thus, the intentional weighting mechanism biases processing of those dimensions. However, if individual features are already specified for the action plan, another process takes place: binding features in event files (Hommel et al., 2001; Hommel, 2004). This might mean interference effects, as the perceptual features are already taken by the action plan.

Aim of Study

The present study aimed to further examine action-perception interference effects with more natural types of actions than those introduced by Müsseler & Hommel (1997a, b). We combined the logic of paradigm of Wykowska et al. (2009) with that of Müsseler & Hommel (1997 a, b). That is, the actions that participants were to perform were grasping or pointing, and the stimuli dimensions in the perceptual task were luminance and size (this was designed after the paradigm of Wykowska et al., 2009 in order to create two action-perception congruency pairs with natural action types: grasping + size vs. pointing + luminance). However, instead of performing a task that is related to visual attention (a visual search task, as in Wykowska et al., 2009), participants performed a task that required only processing of stimuli features and not attentional selection (this characteristic of the paradigm was shared with the protocol of Müsseler & Hommel, 1997 a, b). Through such a paradigm, we were aiming at answering the question of whether interference effects (as observed in Müsseler & Hommel, 1997 a, b) would generalize from simple actions of left/right key presses to more complex and natural action types (grasping or pointing instead of pressing keys on a computer screen).

Design

Participants were informed block-wise if they should compare feature values of two disks within the luminance or within the size dimension. In a size block, participants should say if the two simultaneously presented disks were the same or different size, while in a luminance block participants were asked to respond if the disks were of the same or different luminance. On a trial-by-trial basis they were informed to prepare either a grasping or a pointing movement. There were various disk sets, but overall two shades of luminance were used and two sizes were used. The idea was that to complete the same/different judgment, a participant would have to process the features of the stimuli before making the judgment.

Furthermore, we reasoned that by requiring to process the disks at a feature level, interference effects would be found on action-perception congruency pairs, as in the discrimination task of Carlson and Wykowska (in review). That is, in the luminance block participants should have better performance when they had prepared a grasping movement, relatively to pointing. Conversely, when participants were required to judge the disks based on size they should be better at detecting size difference when they had prepared a pointing movement, as compared to grasping.

Methods

Participants

Data of 33 paid volunteers (13 men) aged from 18 to 31 years (M age: 24) were collected. Seven participants had to be excluded from analyses due to movement error rates or search errors rates over three standard deviations above the sample mean (Movement errors: Lumiannce (M = 2.8%, SD = 2.6%), Size (M = 2.4%, SD = 2.4%) and Search errors: Lumiannce (M = 15.9%, SD = 6.2%), Size (M = 11.5%, SD = 7.3%). All participants were right-handed and all had normal or corrected-to-normal vision. The experiment was conducted with the understanding and written consent of each participant.

Stimuli & Apparatus

Stimuli were presented on a 17’’ CRT screen (85 Hz refresh rate) placed at a distance of 85 cm from a participant. Stimulus presentation was controlled by E–Prime software (Psychology Software Tools, Pittsburgh, PA, USA). Cues specifying what type of action to prepare (i.e., grasping or pointing) consisted of photographs of a right hand performing a pointing or a grasping movement on a white paper cup. The photographs were black and white covering 12.5° x 18.4° of visual angle.

The disks could be presented in one of three pairings (see Figure 3.1 for the luminance and size values of the four disks and Figure 3.1 for visualization of the disks):

SET 1: both disks same in luminance & size, **SET 2**: luminance different (one of the disks darker/lighter than the other one) & size same, **SET 3**: luminance same & size different (one of the disks larger/smaller than the other one), see Appendix I (A, B, C) for visualization of Sets 1, 2, 3. Correct responses were, in the ***luminance*** condition: Respond "*same*" to sets 1 and 3, respond "*different*" to set 2. Correct responses in the ***size*** condition were: respond "*same*" to sets 1 and 2, respond "*different*" to set 3. The relevant dimension conditions (size or luminance) were presented blockwise.

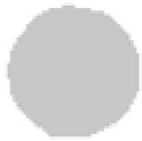
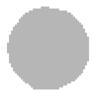
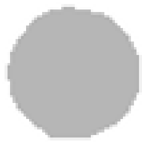
Disk	Features	Luminance (cd/m^2)	Size (angular diameter)	Disks
A	light & small	55	1.55°	
B	light & large	55	1.82°	
C	dark & small	41	1.55°	
D	dark & large	41	1.82°	

Figure 3.1: Details of luminance and size disks. Luminance of the four possible stimuli are given in cd/m2 and their size is given in angular (visual angle) diameter.

The cups on which participants performed the movement (grasping or pointing) were arranged 80 cm in front of the observers below the computer screen. A large dark gray (0.43 cd/m^2) cup, 8 cm (4.5°) in diameter was placed on the left, a middle gray (1.8 cd/m^2) cup, 6.5 cm (3.7°) in diameter in the middle, and a small white (3 cd/m^2) cup, 5cm (2.8°) in diameter on the right.

Procedure

All participants took part in two sessions, one practice session and one experimental session. The practice session in which participants practiced only the movement task was performed in order to facilitate the subsequent experimental session involving two tasks (both the movement task and the perceptual task). There was a minimum of one and a maximum of two days between the practice session and the experimental session. In the practice session, participants performed four blocks of one movement type only (pointing or grasping, 18 trials per block) and two blocks of both types of movement randomly intermixed (54 trials per block). Participants were instructed to place their right hand on the spacebar at all times unless they were making a movement. At the beginning of each trial, a black fixation asterisk was presented for 300 ms, then a movement cue was presented for 100 ms. After this, a blank screen was presented for 500 ms. Then a yellow asterisk was presented above one of three paper cups that were below the monitor. Once the yellow asterisk appeared, the participant should release the spacebar and use their right hand to make the planned movement to the indicated cup. As soon as they released the spacebar the yellow asterisk disappeared from the screen. Participants were instructed to stress accuracy over speed. Also, they were instructed that when grasping the cup they should place all 5 fingers around the cup and when they were pointing to the cup to actually lift their arm and point; and not touch the cup.

At the beginning of the experimental session, participants performed a short warm-up block (18 trials) in which they practiced the movements only, similarly to the movement practice session. After the movement warm-up, participants completed a "movement & perceptual task practice" which consisted of two blocks (each containing 30 trials presented in randomized order). At the beginning of each block participants were instructed that they would later need to judge if two disks were the same or different, based on either their size or luminance (blocked). After instruction regarding which dimension they should use for their judgments (this instruction was given by the presentation of the word Luminance or Size on the screen until the participant pressed the spacebar), a fixation asterisk was presented for 300 ms, then a movement cue was presented for 100 ms. Participants were instructed to prepare the movement they should make but not execute it until later. Then a fixation point was presented for 200 ms. Following this, a two-disk display was presented for 100 ms. There was a black fixation asterisk in the middle of the disk display; one disk was presented on the left of it and one disk was presented on the right. Each disk was equidistant from the asterisk. After the disks were presented, participants were instructed to indicate as quickly and accurately as possible if the two disks were the same or different. They should have made this response by using their left hand to press the "1" key if the disks were the same and the "2" key if they were different (response mappings were counterbalanced across participants). Subsequent to their response, another fixation asterisk was presented for 400 ms, then a yellow asterisk cue came above one of three cups which were aligned in front of the display monitor. This cue indicated on which paper cup they should perform their prepared action. Trial sequence is visualized in Figure 3.2. Order of blocks was counterbalanced.

After completion of this task, participants began the actual experiment (see Figure 3.2); which consisted of the same procedure as the movement & perceptual task practice, but contained 8 blocks, each with 96 trials. Similarly as in the practice session, order was counterbalanced (four blocks of luminance and four blocks of size; each with 48 trials of grasping and 48 trials of pointing).

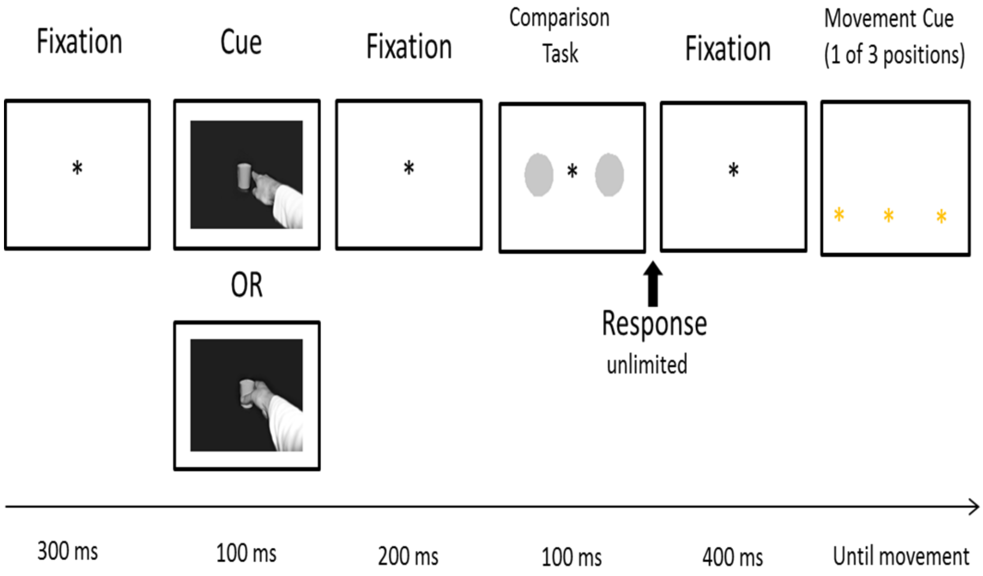


Figure 3.2: Trial sequence: Fixation first, then random presentation of a pointing or grasping cue, comparison task, response, finally, a yellow asterisk randomly appeared in one of three positions, indicating on which cup to perform the indicated action.

Data Analysis

Trials with RTs higher than 1,500 ms in the comparison task were excluded, constituting abnormally long RTs, often due to participants interrupting an experiment to, for example, ask a question to the experimenter (3.75% of trials were excluded). Subsequently, d-primes were calculated and submitted to an analysis of variance (ANOVA) with: relevant dimension (luminance vs. size) and movement (grasp vs. point) as within-subject factors.

In the luminance block 25% of the trials were from SET 1, 25% from SET 3, and 50% from SET 2. In the size block 25% of the trials were from SET 1, 25% from SET 2, and 50% from SET 3. This was done so that response selection (same/different) would be balanced. The two disk sets which should be responded to as “same” actually consisted of different signal types, either both disks exactly the same OR the disks were different on the non-relevant dimension and were the same on the relevant dimension. Therefore, separate analyses were conducted on these two conditions to account for the two types of “same” trials. In one analysis, false alarm rates were from trials with both disks the same (luminance and size: SET 1). In the second analysis, false alarm rates were taken from trials with disks same on the relevant dimension, and different on the other dimension (luminance: SET 3, size: SET 2). In both analyses hit rates were calculated as follows: from luminance: SET 2, and size: SET 3 (see Table 3.1). D-primes were calculated in SPSS (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) using the formula COMPUTE dprime = (PROBIT(Hit)-(PROBIT(FA)).

	Disk Set	Respond "Yes" (different)	Respond "No" (not different)
Luminance	Target (SET 2)	Hit	Miss
	Distractor (SETS 1 OR 3)	False Alarm	Correct Rejection
Size	Target (SET 3)	Hit	Miss
	Distractor (SETS 1 OR 2)	False Alarm	Correct Rejection

Table 3.1: Summary of how hits and false alarms were calculated for luminance and size in the two analyses. For luminance, one analysis calculated false alarms based on SET 1 and the other calculated false alarms based on SET 3. In both analyses hits were calculated based on SET 2. For size, one analysis calculated false alarms based on SET 1 and the other calculated false alarms based on SET 2. In both analyses hits were calculated based on SET 3.

Results

The first analysis of d-primes[3] (false alarms taken from the condition in which both disks were the same) showed a main effect of relevant dimension $F(1, 25) = 27.73$, $p < 0.001$, $\eta_p^2 = 0.53$, with size eliciting larger d-prime (M = 3.24, SE = 0.18) than luminance (M

[3] The results presented here were based on hits (stimuli varying on relevant dimension), which consisted of double the amount of trials than the false alarm trials (stimuli same on both dimensions). To make sure that the effects are not due to unequal number of trials in hits vs. false alarms, for half of the hit trials (randomly selected), an additional analysis was conducted. This way, the amount of hit trials used in the analysis was equal with that of the false alarm trials. These results revealed the same pattern as the results of the main analysis. A main effect of relevant dimension was found $F (1, 25) = 31.58$, $p < 0.001$, $\eta_p^2 = 0.56$, with size eliciting a larger d-prime (M = 3.43, SE = 0.22) than luminance (M = 2.36, SE = 0.12). There was no significant main effect of movement. The significant interaction between relevant dimension and movement remained $F (1, 25) = 12.06$, $p = 0.002$, $\eta_p^2 = 0.33$. Follow-up t-tests revealed a marginally significant difference between grasping and pointing in the luminance condition $t (25)= 1.99$, $p = 0.058$, dz = 0.39 (grasping: M = 2.48, SEM = 0.14 and pointing: M = 2.24, SEM = 0.12), along with a significant difference between grasping and pointing in the size condition $t (25)= 2.83$, $p = 0.009$, dz = 0.56 (grasping: M = 3.13, SEM = 0.16 and pointing: M = 3.72, SEM = 0.30).

= 2.39, SE = 0.12). A significant main effect of movement $F(1, 25) = 6.43$, $p = 0.018$, $\eta_p^2 = 0.21$, with pointing eliciting a larger d-prime (M = 2.92, SE = 0.15) than grasping (M = 2.71, SE = 0.12). Most interestingly, an interaction between relevant dimension and movement was found $F(1, 25) = 14.52$, $p = 0.001$, $\eta_p^2 = 0.37$, see Table 3.2 for the mean d-primes as a function of relevant dimension and movement type, and see Figure 3.3 for visualization of the effects. Follow-up t-tests revealed a significant difference between grasping and pointing in the luminance condition $t(25) = 2.28$, $p = 0.032$, $dz = 0.45$, along with a significant difference between grasping and pointing in the size condition $t(25) = -3.84$, $p = 0.001$, $dz = 0.75$[2]The second analysis (false alarms taken from the condition in which disks in the relevant dimension were the same and in the irrelevant dimension were different) showed only a significant main effect of relevant dimension $F(1, 25) = 14.92$, $p < 0.001$, $\eta_p^2 = 0.38$, with size eliciting a larger d-prime (M = 3.19 SE = 0.22) than luminance (M = 2.41 SE = 0.14). For mean hit rates and false alarm rates, see Appendix 2.

Relevant Dimension	Movement	Mean	SE
Luminance	Grasp	2.51	0.14
	Point	2.26	0.12
Size	Grasp	2.91	0.15
	Point	3.57	0.24

Table 3.2: Mean d-primes as a function of relevant dimension and movement type.

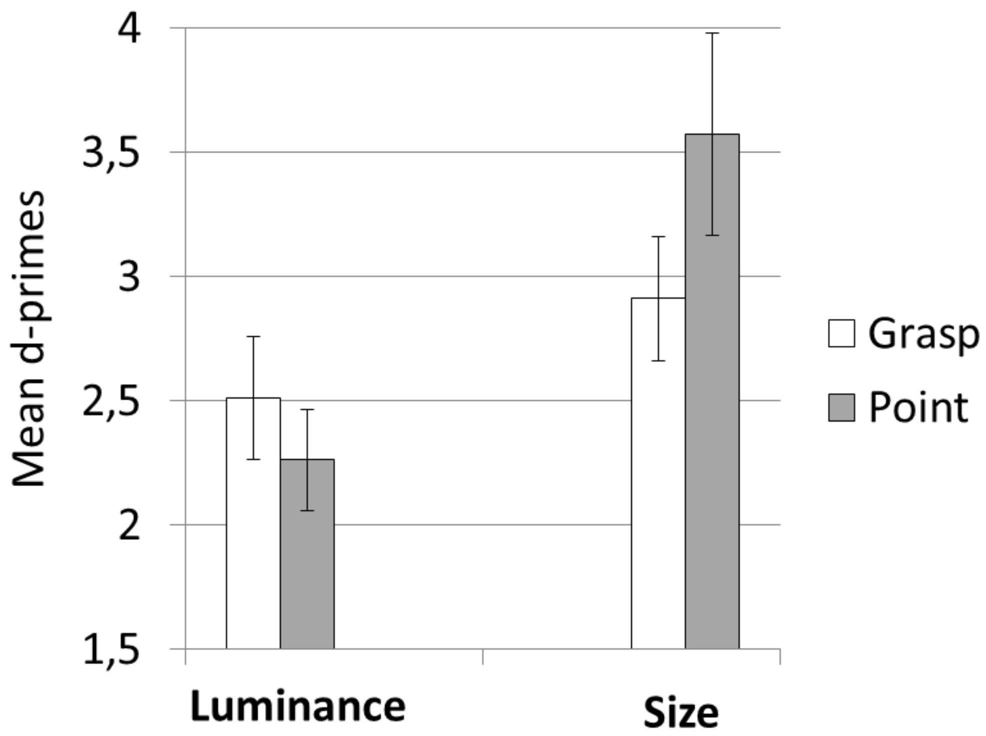


Figure 3.3: Average d-primes as a function of luminance (left) and size (right) dimensions as well as grasping (white bars) vs. pointing (grey bars) movements. Error bars represent within-subjects confidence intervals with 95% probability criterion, calculated according to the procedure described in Cousineau (2005).

Discussion

The aim of this study was to examine action-perception biases of processing perceptual features. We designed the experiment so that natural actions (grasping or pointing) would be coupled with perceptual dimensions (size or luminance). Yet, following previous study (Carlson & Wykowska, in review) we targeted at processing at the level of perceptual features, and not dimensions in order to increase the likelihood of observing interference effects, rather than congruency effects. This was done in order to examine whether interference effects of similar type as in Müsseler and Hommel (1997a, b) would generalize from simple actions such as left/right key presses to more complex and natural actions such as grasping or pointing. To meet the aims of this study, we designed an experiment in which two disks were simultaneously presented on the computer screen while participants prepared for a grasping or a pointing movement. The disks could be the same or different on a given dimension (size or luminance). Participants were to compare the two disks and respond "same/different", respectively.

As in some trials the disks to which participants were to respond "same" were indeed physically identical, while on a number of trials they were different in the irrelevant dimension, two separate analyses were conducted on these two conditions. The disk set which was different on the relevant dimension, but the same on the irrelevant dimension (50% of trials), requiring a different response, was considered the target set and used to calculate hit rates for both analyses. Participants' sensitivity to the difference between the disks was measured with d-primes.

In the first analysis (false alarm rates from trials with both disks the same) a main effect of dimension was found with size eliciting a larger d-prime than luminance, which shows that size difference might have been easier to detect than luminance. More interestingly, a significant interaction between dimension and movement was found indicating that when participants were to discriminate the disks based on luminance they had higher sensitivity to the difference when they had prepared a grasping movement, relative to pointing. Conversely, when detecting size difference, participants had higher sensitivity in the pointing condition, relative to grasping. This is in line with results of Carlson and Wykowska (in review) who showed action-perception interference effects when feature-based processing was required. The present study extends the previous findings by showing that the action-perception biases in feature-based processing generalize from an attentional task to a lower-level perceptual task where attentional selection is not required.

In the second analysis (false alarm rates from trials with disks different on the irrelevant dimension) no interaction between dimension and movement was found. This might indicate that the irrelevant dimension was still processed to some extent and thus the effects might have cancelled out.

The observed interference effects support the idea of event files put forward in Hommel et al. (2001). According to this idea, perceptual and action features are bound together within event files when an action planning or perceptual event takes place. Once features are bound together, re-use of a feature from within an event file is effortful (as compared to usage of an entirely new feature), as it needs to be “unbound” and event file needs to be updated. In the case of the present study, when grasping was prepared, size features might have been bound to the grasping event, thus being less accessible to the perceptual task of comparing the two size features. Analogously, luminance features might have been bound to the pointing action, thereby making them less accessible for the luminance comparison task. Interestingly, the action-perception biases have been observed in the form of interference, and not congruency effects. As in Carlson and Wykowska (in review), we argue that this is due to that processing at the level of features was involved in the task of the present study. We propose that during action planning the two mechanisms (intentional weighting resulting in congruency effects, and feature binding resulting in interference effects) might be present simultaneously. However, dependent on whether the task requires processing at the level of dimensions or features, one or the other mechanism is observed, because intentional weighting operates at the level of dimensions, while feature binding involves processing at the level of features.

In sum, the present results extend previous findings on action-perception links by showing that action planning affects perception also when complex and natural movements are being performed in parallel to a perceptual task. Interestingly, the results were in the same direction as findings of Müsseler & Hommel (1997a, b), that is interference (not congruency) effects were observed. This is presumably due to that processing required for the perceptual task was at the level of features, not dimensions, which would be in line with the arguments put forward in Carlson and Wykowska (in review). Thus, taken together, the present study showed that action-perception interference effects are not limited to simple key presses but generalize also to complex actions such as grasping and pointing. Importantly, interference effects are observed when feature-based processing is involved in the task.

Chapter 4

The Role of Feature Discrimination in Action-Perception Interference Effects: An EEG Study

Abstract

Prior studies have supported the idea that action planning and perception are tightly coupled and bidirectional influence each other (Prinz, 1987, 1997; Hommel et al., 2001). Studies investigating this idea have found different effects. Some studies have found action-perception interference effects (Müsseler and Hommel, 1997 a,b); while others have found action-perception congruency effects (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö,2011; Wykowska, Hommel, & Schubö, 2012). It has been suggested by (Carlson & Wykowska, in review, Chapter 2; Chapter 3) that action-perception interference effects occur when features that are shared between a stimulus and a prepared action impairs identification or detection of a stimulus. Whereas, action-perception congruency effects occur when stimulus dimensions congruent with a planned action are processed with priority, relative to dimensions that were action-incongruent. The current study uses the paradigm of Chapter 3 in conjunction with electroencephalography (EEG) to investigate the early sensory component P1 and the late discrimination component N1. It is thought pre-selective weighting of dimensions will be reflected with a pattern that supports action-perception congruency effects in P1. However, since the comparison task requires discrimination of the features of the stimuli it is thought that later processing around the time of the N1 component will reflect action-perception interference effects. It is also expected that RTs from the comparison task will reflect action-perception interference effects. Results show possible support for action-perception congruency effects in P1, but results for N1 are not clear.

Introduction

Over the years evidence has accumulated to support the idea that action planning and perception are tightly coupled and bidirectionally influence each other (Prinz, 1987, 1997; Hommel et al., 2001). However, some studies have found action-perception interference effects (Müsseler and Hommel, 1997 a,b); while others have found action-perception congruency effects (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö,2011; Wykowska, Hommel, & Schubö, 2012). It seems that action-perception interference effects occur when features that are shared between a stimulus and a prepared action impair identification or detection of a stimulus. This does not occur in conditions where features are distinct. Action-perception congruency effects seem to occur when stimulus dimensions congruent with a planned action are processed with priority, relative to dimensions that were action-incongruent. For instance, Fagioli et al. (2007) found that when preparing a grasping movement detection of size oddballs was facilitated, whereas preparing a pointing movement facilitated detection of location oddballs. Further studies have supported similar congruency pairs, showing that preparing a grasping movement enhances detection of a size target, while preparation of a pointing movement enhances detection of luminance targets (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö, 2012). Interestingly, also a reverse pattern has been observed: preparing a grasping movement enhanced perception of luminance, while preparation of a pointing movement enhanced perception of size. This pattern tends to be seen when processing at the level of features is involved (Carlson & Wykowska, in review, see Chapter 2; Chapter 3).

Taken together, the pattern of results across various studies suggests that action-perception interference effects involve processing features and action-perception congruency effects involve processing dimensions. This idea has been addressed by (Carlson &

Wykowska, in review, see Chapter 2) who showed that when participants had to perform a discrimination task by discriminating the features of a size target, interference effects were observed, namely participants were faster in making the discrimination when they had prepared a pointing movement than when they had prepared a grasping movement. When the same participants had to detect a size pop-out target, this only required knowing the dimension of the target, they were faster when they had prepared a grasping movement as compared to a pointing movement, reflecting action-perception congruency effects.

To further investigate the role of feature-level processing in action-perception interference effects the study reported in Chapter 3 created a paradigm where in participants prepared either a grasping or pointing movement, then two disks were presented, participants were required to compare the feature values of the two disks to judge if they were the same or different. After this, they performed their prepared movement. Participants were informed block-wise if they should compare the disks based on the luminance or size dimension. To further clarify, during size blocks, participants should say if the two simultaneously presented disks were the same or different size, while in a luminance block participants should say if the disks were of the same or different luminance. Here it was found that congruent action-perception pairs resulted in lower sensitivity (as measured by d-prime) in the perceptual task, relative to incongruent pairs. This supports the idea that interference effects occur when participants must discriminate the features of a stimuli.

In the current study the paradigm of Chapter 3 was used in conjunction with electroencephalography (EEG) to investigate the early sensory component P1 and the late discrimination component N1. In the past the P1 component was thought to reflect mainly spatial attention (Luck et al., 1993; Luck and Hillyard, 1995), but in recent years research has begun to suggest that P1 might not only reflect spatial attention (Taylor, 2002; Zhang and Luck, 2009). For instance, Wykowska & Schubö (2012) investigated the pre-selective weighting of dimensions with regards to action intentions as reflected in the modulation of P1. In this study it was found that when participants prepared either a grasping or pointing movement, and had to detect if a luminance or size target was present in a search display, a modulation of P1 was found. Across the occipital electrodes (O1/O2 and PO7/PO8) in the luminance condition there was a more enhanced positivity in P1 when a pointing movement was prepared relative to when a grasping movement was prepared. No significant effects were found in the size condition.

Therefore, it is expected that P1, around the time window of 100 ms post-stimulus, should reflect action-perception congruency effects due to pre-selective weighting of dimensions. In the study reported in this chapter, a similar pattern to Wykowska & Schubö (2012) was expected in terms of modulation of early ERP components related to processing size or luminance by action planning. It was expected that since a discrimination task, which requires feature-based processing, was being used, action-perception interference (not congruency) effects should be found (the reverse pattern as in Wykowska & Schubö, 2012). We expected the latter effects to appear in the N1 component which has been shown to potentially reflect discrimination (Vogel & Luck, 2000), namely in the late N1 component (inferoposterior component) which was determined by Vogel & Luck (2000) to have its peak amplitude 140 – 180 ms post-stimulus at lateral occipital electrodes. So it was expected in this study that in the luminance condition there would be a more negative amplitude for the N1 component during grasping trials than during pointing trials and in the size condition there would be a more negative amplitude for the N1 component during pointing trials than during grasping trials. It was expected that these results would also be reflected in RTs, with the grasping resulting in faster RTs than pointing in the luminance condition and pointing resulting in faster RTs than grasping in the size condition.

Aim of Study

The aim of this study was to use the same paradigm as in Chapter 3 in conjunction with electroencephalography (EEG) to investigate the early sensory component P1 and the late discrimination component N1. It is thought that the P1 component should reflect pre-selective weighting of dimensions with a pattern that supports action-perception congruency effects. However, since the comparison task of this study required discrimination of the features of the stimuli, it was thought that action-perception interference effects would be observed in the in later processing, around the time of the N1 component, shown by (Vogel & Luck, 2000) to reflect discrimination processes, It was also expected that RTs from the comparison task would reflect action-perception interference effects.

Materials and Methods

Participants

Eighteen participants (11 women, 7 men) aged from 18 to 31 years (mean age: 24.8) took part. All were paid volunteers who were right-handed and had normal or corrected to normal vision. The experiment was conducted with the understanding and consent of each participant.

Stimuli and Apparatus

The same stimuli and apparatus were used as in Chapter 3 (see pages 63 - 64).

Procedure

One to two days before the experiment proper participants took part in a practice session where they practiced first the movement task alone, then the movement task and the comparison task. The movement only section of the practice was the same as (Chapter 3, page: 65), four blocks of one movement type only (pointing or grasping, 18 trials per block) and two blocks of both types of movement randomly intermixed (54 trials per block).

In the movement and comparison task part of the practice participants completed two blocks of size comparison and two blocks of luminance comparison, each block contained 30 trials. Participants were instructed to place their right hand on the spacebar at all times unless they were making a movement. A trial sequence (see Figure 4.1), consisted of a black fixation asterisk being presented for 300 ms, then a movement cue was presented for 100 ms, next a fixation asterisk for 200 ms, then the comparison task for 100 ms, the comparison response could be made in an unlimited amount of time, after this another fixation asterisk for 400 ms, this was followed by an yellow asterisk which could appear in one of three positions and indicating which cup the prepared action should be made towards. This asterisk disappeared when the participants released the spacebar to make their movement to the cup. Finally, after their movement was complete a blank ITI was presented for 300 ms.

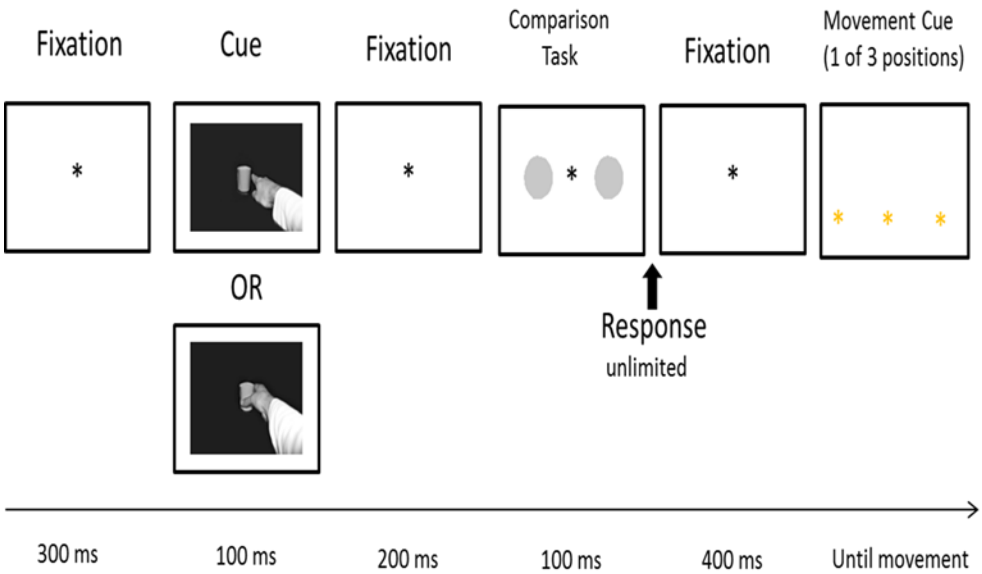


Figure 4.1: a standard trials sequence. Beginning with fixation, then a randomized action cue, followed again by fixation, then the comparison task, after the participant’s response there was another fixation asterisk, then finally a yellow asterisk would randomly appear in one of three locations, showing the participant which cup to perform the prepared action to.

On the day of the experiment proper the participants first practiced just the movements again (18 randomized trials), then the movement and comparison task was practiced for 2 blocks (1 luminance and 1 size), 30 trials each. Before starting the experiment proper participants were told if they did not reach 70% accuracy in the blocks they would not be allowed to continue the experiment. The EEG experiment consisted of 12 blocks (6 luminance and 6 size) and each block was 48 trials long. After these blocks participants performed 6 blocks (48 trials each block) wherein they performed only the movement task while EEG was being recorded, these trials served as catch trials.

Catch trials were introduced so that a subtraction of ERP potentials could be performed allowing for the extraction of the overlapping cue-locked ERPs so that only comparison task-locked ERPs were left. The catch trials differed from the standard trials in that instead of a comparison task display a blank display was presented for 100 ms. Also, since the participants did not need to perform the comparison task, a blank display was presented for 400 ms during the time when they would typically be responding to the comparison task.

EEG Recording

EEG was recorded with Ag-AgCl electrodes from 64 electrodes. The electrodes were mounted on an elastic cap (EASYCAP, GmbH, Germany), according to the International 10-20 System. All electrodes were referenced to Cz and re-referenced offline to the average of all electrodes. Electrode impedances were kept below 5 kΩ. Sampling rate was 500 Hz with a High-Cutoff Filter of 125 Hz.

Data Analysis

EEG data

Only trials with correct movement and correct comparison task responses were analyzed. Furthermore, trials with RTs above 1,500 ms in the comparison task were excluded. Two participants were excluded due to extensive eye blinks. The P1 analyses focused on electrodes O1, O2, PO7, PO8, where early visual processing is most pronounced. The N1 focused on electrodes O1, O2, PO7, PO8, P7, P8, similar to Vogel & Luck (2000).

EEG was averaged offline over 600-ms epoch, this included a 200-ms pre-stimulus baseline, epochs were time locked to the onset of the comparison task. Trials with eye movements and blinks on any recording channel were excluded from analyses. This was indicated by any absolute voltage difference in a segment exceeding 80µV or voltage steps between two sampling points exceeding 50µV. Channels which included other artifacts such as amplitude exceeding ±80µV or any voltage was lower than 0.10µV for a 100 ms interval were excluded. Raw data was filtered offline 40-Hz high-cutoff filter (Butterworth zero phase, 24 dB/Oct).

In the Luminance condition the two disks were of different luminance in 50% of the trials, different size in 25% of the trials, and the same in 25% of the trials. In the Size condition the two disks were of different size in 50% of the trials, different luminance in 25% of the trials, and the same in 25% of the trials. Therefore, it was not possible to directly compare the luminance and size conditions on the different luminance or the different size trials since the amount of trials differed, but it was possible to compare the conditions on the same trials since the amount of trials was equal. Therefore, the conditions (luminance and size) will be analyzed separately with grasping and pointing being compared on each trial type set separately (different luminance, different size, same). Finally, the same trials will be used to compare the conditions and movement types.

Behavioral data

Incorrect movement and search responses were excluded, as well as trials with RTs above 1,500 ms in the comparison task. Participants who were excluded from the EEG data analyses were also excluded from the behavioral analyses. Analysis reflects the stipulations mentioned in the EEG Data section. Hence, the conditions (luminance and size) will be analyzed separately with grasping and pointing being compared on each trial type set separately (different luminance, different size, same). Finally, the same trials will be used to compare the conditions and movement types.

Results

Event-Related Potentials

Early sensory ERP component: P1

A 2 × 4 ANOVA with the factors movement type (grasping vs. pointing) and electrode (O1, O2, PO7, PO8) conducted on the mean amplitudes of the ERP waveform within 80–140 ms time window [representing the latency of the P1 component, determined around (±30 ms) the grand average peak latency] for luminance and size trials separately.

Luminance: no significant results were found for any of the trial types.

Size: on the different luminance trials no significant results were found. On the different size trials no interesting results were found. On the same trials (see Figure 4.2) there was a main effect of movement $F(1,15) = 6.84$, $p < 0.019$, $\eta p^2 = 0.31$ with grasping having a more enhanced positivity ($M = 3.63$, $SEM = 0.68$) than pointing ($M = 2.58$, $SEM = 0.62$).

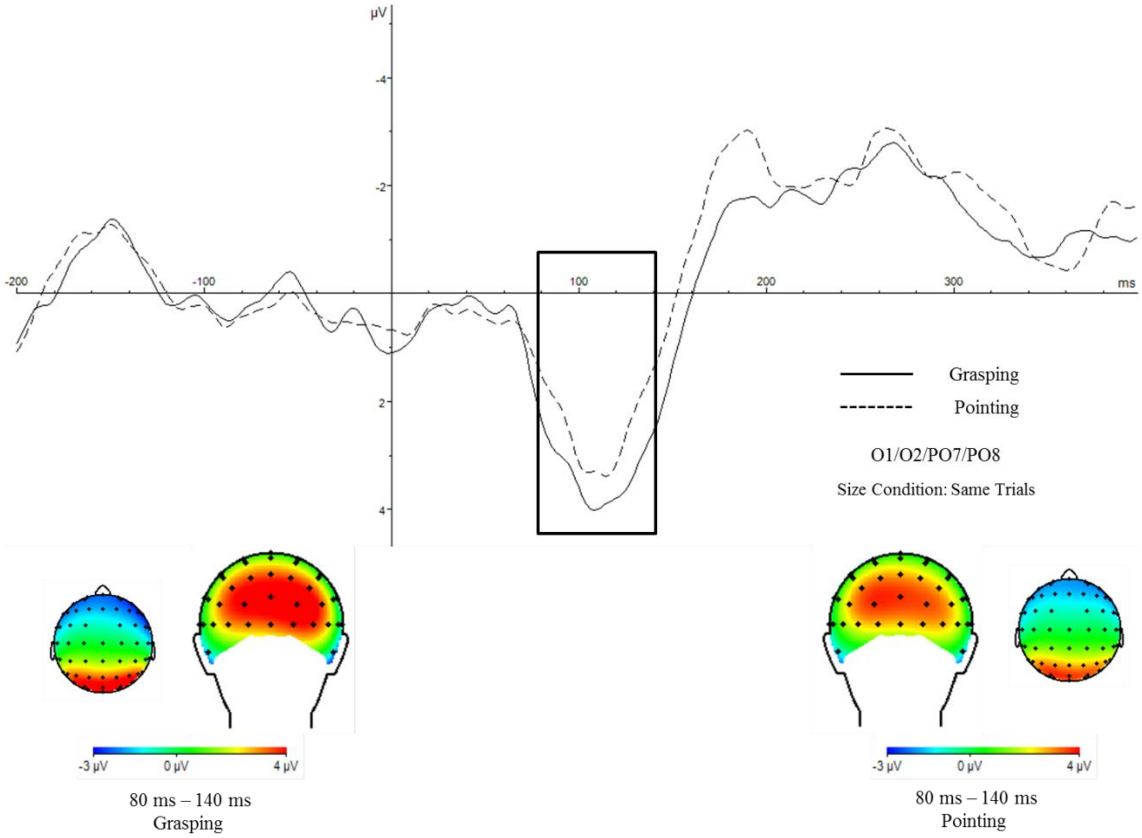


Figure 4.2: Upper: Grand average ERP waveforms of the P1 component between the time window of 80 – 140 ms in the size condition on same trials. The grand average waveforms are locked to the search display and pooled across occipital electrodes O1, O2, PO7, and PO8. The solid line represents grasping and the dotted line represents pointing. A black box encompasses the time frame of the P1 component. Lower: Topographical maps of voltage distribution for the 80 – 140 ms time interval for the size condition on same trials. The larger images represent the posterior view and the smaller images represent the top view.

A 2 x 2 x 4 ANOVA with the factors task type (size vs. luminance), movement type (grasping vs. pointing) and electrode (O1, O2, PO7, PO8) was performed on the same trials (see Figure 4.3 and Figure 4.4). There was a main effect of condition $F(1,15) = 22.64$, $p < 0.001$, $\eta p^2 = 0.60$ with size ($M = 3.10$, $SE = 0.62$) with size having a more enhanced positivity than luminance ($M = 1.62$, $SE = 0.49$) and an interaction of condition and movement $F(1,15) = 36.08$, $p = 0.011$, $\eta p^2 = 0.36$. Follow-up t-tests revealed for size a significant difference $t(15) = 2.62$, $p = 0.019$ with grasping having a more enhanced positivity ($M = 3.63$, $SEM = 0.68$) than pointing ($M = 2.58$, $SEM = 0.62$). Grasping was significantly $t(15) = 4.78$, $p < 0.001$ more positively enhanced in the size condition ($M = 3.63$, SEM = 0.68) than the luminance condition (M = 1.40, SEM = 0.43) and pointing was significantly $t(15) = 2.19$, $p = 0.044$ more positively enhanced in the size condition (M = 2.58, SEM = 0.62) than the luminance condition (M = 1.84, SEM =0.65).

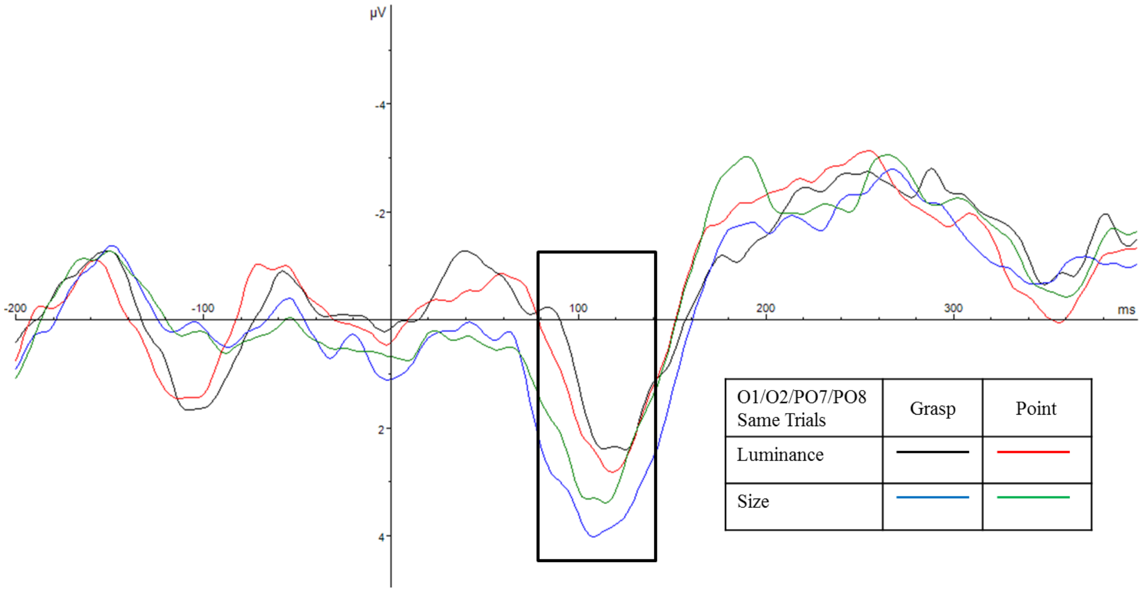


Figure 4.3: Grand average ERP waveforms of the P1 component between the time window of 80 – 140 ms for both the size and luminance conditions on same trials. The grand average waveforms are locked to the search display and pooled across occipital electrodes O1, O2, PO7, and PO8. A black box encompasses the time frame of the P1 component. The black line represent grasping trials in the luminance condition, the red line represents pointing trials in the luminance condition, the blue line represents grasping trials in the size condition, and the green line represents pointing trials in the size condition.

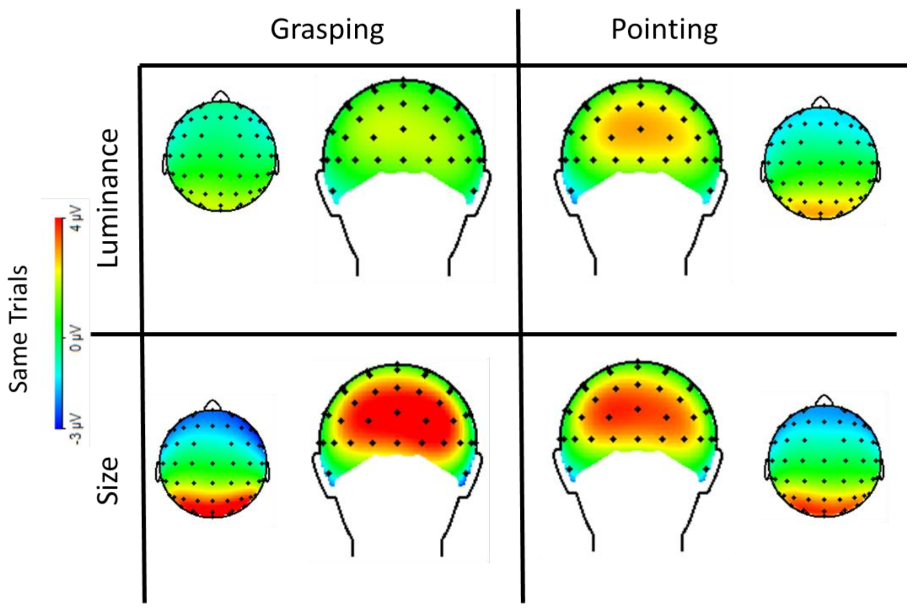


Figure 4.4: Topographical maps of voltage distribution for the 80 – 140 ms time interval for the luminance condition (upper rower) and the size condition (lower row) on same trials with the left column containing grasping trials and the right column containing pointing trials. The

larger images (four central images) represent the posterior view and the smaller images (four outer images) represent the top view.

In summary, the luminance condition showed no significant effects on any of the trial types. Interestingly, in the size condition a main effect of movement on the same trials was found with grasping having a more enhanced positivity than pointing. The comparison of the conditions on the same trials revealed a main effect of condition with size being more positive than luminance and an interaction between condition and movement type showing size to be more positively enhanced than luminance for both grasping and pointing. Also, within the size condition grasping had a more enhanced positivity in comparison to pointing.

Discrimination ERP component: Late N1

A 2 × 6 ANOVA with the factors movement type (grasping vs. pointing) and electrode (O1, O2, PO7, PO8, P7, P8) was conducted on the mean amplitudes of the ERP waveform within the 160–200 ms time window for luminance and size trials separately.

Luminance: none of the trial types: different luminance, different size, or same trials showed significant interesting results.

Size: neither the different luminance nor same trials showed significant results. On the different size trials (see Figure 4.5) there was a main effect $F(1,15) = 10.91$, $p = 0.005$, $\eta p^2 = 0.42$ with pointing being more negative ($M = -2.71$, 0.81) than grasping ($M = -1.66$, 0.81).

A 2 x 2 x 6 ANOVA with the factors task type (size vs. luminance), movement type (grasping vs. pointing) and electrode (O1, O2, PO7, PO8, P7, P8) was performed on the same trials. No significant results were found here.

In summation, the luminance condition showed no significant interesting effects. The size condition showed a main effect of movement type on different size trials with pointing being more negative than grasping. The comparison of the conditions on the same trials revealed no significant results.

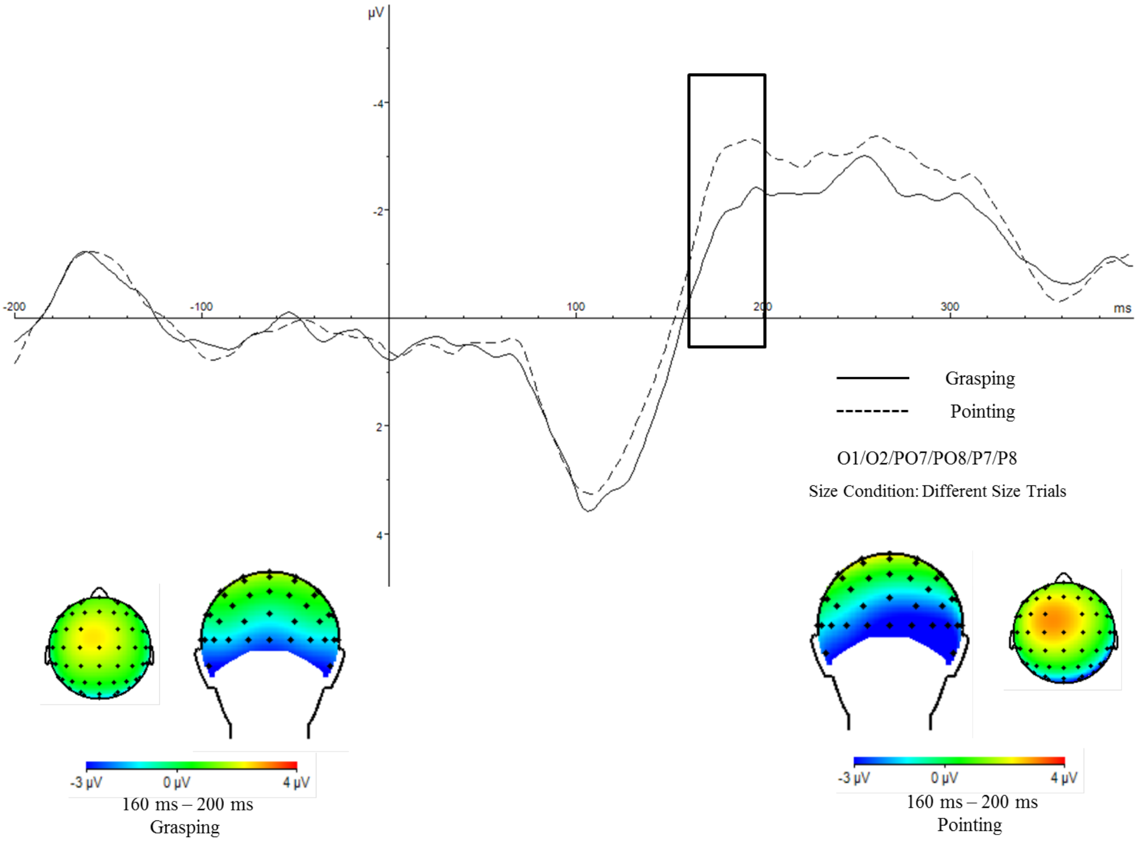


Figure 4.5: Upper: Grand average ERP waveforms of the N1 component between the time window of 160 – 200 ms in the size condition on different size trials. The grand average waveforms are locked to the search display and pooled across occipital electrodes O1, O2, PO7, PO8, P7, and P8. The solid line represents grasping and the dotted line represents pointing. A black box encompasses the time frame of the N1 component. Lower: Topographical maps of voltage distribution for the 160 – 200 ms time interval for the size condition on different size trials. The larger images represent the posterior view and the smaller images represent the top view.

Behavior

In the Luminance condition t-tests revealed no significant difference between grasping and pointing on the different luminance or the different size trials. On the same trials there was a significant difference $t(15) = 2.26$, $p = 0.039$ with pointing ($M = 709.17$, $SEM = 40.39$) being faster than grasping ($M = 750.23$, $SEM = 44.02$).

In the size condition t-tests revealed no significant difference between grasping and pointing on the different luminance or the same trials. On the different size trials a significant difference was found $t(15) = 3.83$, $p = 0.002$ with pointing ($M = 659.51$, $SEM = 33.24$) being faster than grasping (M = 687.71, SEM = 35.03). A 2 x 2 ANOVA with the factors condition (luminance vs. size) and movement type (grasp vs. point) was performed on the same trials. There was a main effect of movement $F(1,15) = 5.37$, $p = 0.035$, $\eta p^2 = 0.26$ with pointing being faster (M = 698.62, SEM = 38.30) than grasping (M = 725.94, SEM = 41.60).

Discussion

The current study used the paradigm of Chapter 3 in conjunction with electroencephalography (EEG) to investigate the pre-selective weighting of dimensions which was suspected to reflect action-perception congruency effects by modulation of the P1 component. Later processing and discrimination of the features of the stimuli should be reflected in the N1 component by a modulation that shows action-perception interference effects. Furthermore, it was suggested that RTs from the comparison task should reflect action-perception interference effects.

In the ERP analysis for both components, P1 and N1, the conditions (size and luminance) were analyzed separately for all trial types (different size, different luminance, same) and ANOVAs were conducted on movement type and electrode. Then for the same trials the conditions, movement type, and electrodes were compared.

The P1 component was investigated in the time window of 80-140 ms on the electrodes O1, O2, PO7, and PO8. This revealed in the size condition on same trials size showing a more enhanced positivity for both pointing and grasping relative to luminance and that within size itself grasping shows a more enhanced positivity than pointing. The enhanced positivity for the size condition compared to the luminance condition shown here when two stimuli that are identical (on size and luminance) are to be compared may solely reflect the fact that it was easier to determine if the circles were the same size, than it was to determine if they were the same luminance. A modulation of the P1 component with grasping having a more enhanced positivity relative to pointing in the size condition seems to reflect action-perception congruency effects. This may be evidence that dimensional weighting effects can influence the early sensory P1 component (80–140 ms), in that dimensions which should be processed with priority and are congruent with the task at hand can lead to modification of this early sensory component.

The N1 component was investigated in the time window of 160–200 ms on electrodes O1, O2, PO7, PO8, P7, and P8. In the luminance condition no significant interesting effects were found.

In the size condition on the different size trials a main effect was found with pointing being more negative than grasping. This is interesting, as action-perception interference effects seem to be reflected in the size condition, but it seems here that the effect may actually be driven by an overall enhanced effect of pointing. It can be seen in the behavioral results that in the luminance condition on the same trials pointing was faster than grasping. In the size condition on the different size trials pointing was faster than grasping (such as the N1 results discussed above). The ANOVA comparing conditions and movement type on the same trials also revealed a main effect of pointing being faster than grasping. A similar effect has been reported by Wykowska & Schubö (2012). When they analyzed target absent trials in the time window of 130–300 ms they found a more enhanced negativity for pointing relative to grasping. Although the results of Wykowska & Schubö (2012) cannot be directly compared to the results here, it does suggest that pointing may generally result in a more negative waveform in the later time window than grasping does. The faster RTs for pointing compared to grasping and the enhanced negative wave for pointing in the N1 time window reported here may reflect that pointing is a simpler action than grasping. Therefore, it may be that when less cognitive resources are required to prepare the action that the participant has more resources to process the comparison task.

In conclusion, these results seems to suggest that perhaps action-perception congruency effects based on dimensional weighting may cause modulation of the P1 ERP component. These results seem to show that early sensory process can be influenced by the congruency of an action with a task relevant dimension. However, it is still not clear if late processing, namely discrimination of features, has a role in action-perception interference effects. It may be wise to conduct an EEG study to investigate these effects in a paradigm similar to Carlson & Wykowska, in review, see Chapter 2.

Chapter 5

Enhancing Joint Attention Skills in Autistic Children via a Robot

Abstract

Autism spectrum disorder (ASD) children tend to lack joint attention (JA) skills which may lead to a lack of development in their communication and social skills. Joint attention is the sharing of attention between a person (child), another person, and an object or event (Charman, 2003; Leekam, López, & Moore, 2000). It has been suggested that there are two separate mechanisms for joint attention. One mechanism functions to initiate joint attention (IJA) and the other mechanism functions to respond to joint attention (RJA) (Mundy & Crowson, 1997). The current experiment was conducted to expand upon the research done by Kajopoulos, et al. (2015) where in a robot named "CuDDler" (A*Star) served to enhance the joint attention skills of Autistic children. The study consisted of pre and post-tests to measure the children's joint attention skills via the abridged Early Social Communications Scale, ESCS (Mundy et al., 2003). One group received robot training and the other was a control group who did not receive training. The current results showed a significant improvement in the treatment group's scores from pre to post-test. However, there was no significant difference in the post-test scores between the treatment and control groups. Further investigation into these data suggests that this therapy may be the most beneficial for children with ASD who are less functional.

Introduction

Autism spectrum disorder (ASD) is described by the DSM-5 as a range of disorders characterized by social deficits and communication difficulties, stereotyped or repetitive behaviors and interests, sensory issues, and in some cases, delayed cognitive development (American Psychiatric Association, 2013). There is currently no cure for ASD, but providing therapy early can greatly reduce symptoms and increase abilities. Areas of focus in therapy include language, communication, and social skills (Meindl & Cannella-Malone, 2011; Mundy, Sigman, & Kasari, 1990; Whalen & Schreibman, 2003).

In this paper the specific skill of joint attention (JA) will be addressed. Joint attention is the sharing of attention between a person (child), another person, and an object or event (Charman, 2003; Leekam, López, & Moore, 2000). It has been suggested that there are two separate mechanisms for joint attention. One mechanism functions to initiate joint attention (IJA); e.g., showing an object to others; the other mechanism functions to respond to joint attention (RJA); e.g., turning one's head to look in the direction that another person is pointing and looking (Mundy & Crowson, 1997). Typically joint attention develops between around 6 to 12 months of age (Charman, 2003; Moore & Dunham, 2014). It is thought that this skill may be pivotal in the acquisition of language (Meindl & Cannella-Malone, 2011), since when a child attends to their parent who is saying the name of an object and pointing to it, the child will likely associate this name with the object. However, children diagnosed with ASD may not follow gaze or pointing gestures as readily as their typically de-veloping peers, they also may make less eye contact and initiate less showing or pointing gestures (Charman, 2003; Meindl & Cannella-Malone, 2011; Taylor & Hoch, 2008). This lack of JA in ASD children may lead to a lack of development in their communication and social skills.

Thankfully, research by (Charman, 2003; Meindl & Cannella-Malone, 2011; Mundy et al., 1990) has shown that early intervention which increases non-verbal communication skills may lead to increased language and social development in children with ASD. Interestingly, in the past years a new type of intervention has started to be used for children with ASD.

This new type of intervention is social robotics (Cabibihan, Javed, Ang, & Aljunied, 2013; Dautenhahn, 2003; Scassellati, Admoni, & Matarić, 2012). It is thought that robots provide a suitable platform for therapy for children with ASD because, their behavior is predictable and they have few facial expressions. Therefore, it may be easier for a child with ASD to process and interpret a robot's behavior and minimalistic expressions. Furthermore, a robot can interact with children all across the spectrum of ASD with a standardized behavior and voice; whereas human therapists may show variability in voice, behavior, ect. depending on the severity of the child's ASD.

The current experiment was conducted to expand upon the research done by Kajopoulos, et al. (2015) where in a robot named "CuDDler" (A*Star) served to enhance the joint attention skills of Autistic children. This expansion included more sessions, testing more children, testing children from the whole spectrum of ASD, and comparing a robot treatment group with a control group. The study consisted of pre and post-tests to measure the children's joint attention skills via the abridged Early Social Communications Scale, ESCS (Mundy et al., 2003). One group received robot training and the other was a control group who did not receive training. Based on Kajopoulos, et al. (2015) it was expected that the robot training group would show improvements in RJA skills, but not IJA skills. It was further hypothesized that the robot training group would show improvements in RJA skills, while the control group would not.

Methods

Participants

20 children (Mean age 5.3, SD = 0.7), age range: 4 to 6 years, all male, all diagnosed with ASD and taking no medications took part in the experiment. Participants were English

speakers of Singaporean decent. Participants were randomized either to the intervention group (n = 10), receiving robot intervention in addition to ordinary pre-school program, or to the control group (n = 10), receiving ordinary preschool pro-gram only. Randomization was done in a way that the two groups similarly represented the ASD spectrum. Additionally, the "assessment, evaluation and programming system for infants and children" (AEPS) scores were collected for the children. AEPS is a testing system which assesses children's current skill levels and can be used to monitor progress and aid in identifying disability. AEPS scores are calculated for the following skills: fine motor, gross motor, cognitive, adaptive, social communication, and social. The scores between treatment and control group were not significantly different. Parents were recruited via the early intervention center THK EIPIC Centre (Singapore).

Stimuli and Apparatus

An embodied robot (CuDDler, A*Star) was controlled by the experimenter via a computer interface (operating system: Windows 7) which interacted with a smartphone (Google Nexus 4) inside of the robot. The control system for CuDDler was programmed using android java and C++. Two BePhones (resolution: 640 x 480 and screen size: 136.6 x 70.6 mm) were used to present picture stimuli. The programming language android java was used for displaying stimuli. The screens were placed left and right of the robot with at a distance of ~ 40 cm (11° of visual angle of participants). The screens were tilted approximately 45° relative to the robot, this caused it to seem as if the robot could "see" the stimuli when it moved its head (see Figure 5.1).

The stimuli consisted of 10 colorful line drawings of various objects (star, apple, ball, candle, flower, hat, heart, ice cream, plane, sweet) in 4 colors red, blue, green or yellow. Each session consisted of 20 trials with all objects in all colors appearing once. In each trial the same object (ex. star) was presented on both phones, but the objects were of different color (ex. left star yellow and right star green). The stimuli were fit to the center of the phone screens (136.6 x 70.6 mm) and covered 2° in height and approximately 3.5° in width of visual angle of participants. On each trial the robot randomly moved its head approximately 2.3° in visual angle of participants either left or right from the midline with equal probability. The participants were seated 200 cm from the robot. A table with a mouse was located in front of participants, they were require to press the mouse key which corresponded to the side of space the robot directed its attention to.

Procedure

The experiment consisted of three phases. Phase 1 was a pre-test to measure the children's joint attention skills via the abridged Early Social Communications Scale, ESCS (Mundy et al., 2003). Phase 2 was the robot training or control sessions. Phase 3 was the administration of the ESCS as a post-test.

The pre- and post-tests lasted approximately 10 minutes. As we were only interested in measuring joint attention skills only 3 parts of the ESCS were used, the Object Spectacle Task (1 x), the Gaze Following Task (2 x) and the Book Presentation Task (2 x).

The robot training (see Figure 5.1) consisting of a training session to familiarize the children with the task, then 8 sessions of approximately 10 minutes were conducted over a period of 4 weeks (2 sessions per week). The control group participated in the same amount and length of sessions, only that they played with a teddy bear or other toys during this time instead of interacting with the robot.

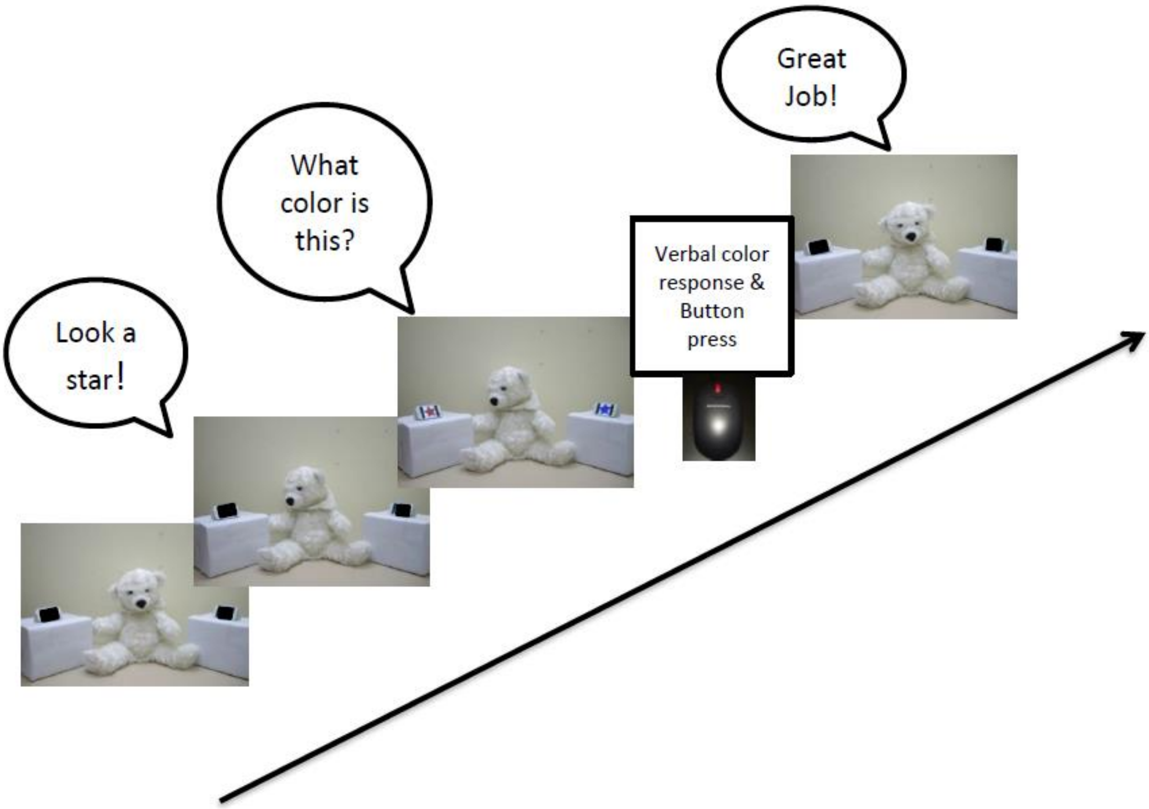


Figure 5.1: Trial Sequence Example: 1. Robot looks straight ahead 2. Turns head and says, "Look a star!" 3. Two stars appear 4. Robot asks, "What color is this?" 5. Child gives verbal response naming the color (correct here = red) and presses the mouse button (correct = left). 6. Robot looks at child while saying "Good job" and moving its arms and head around 7. Return to starting position. Image credit to: Kajopoulos, J. (2014) unpublished Master's thesis.

Data Analysis

Scores for IJA and RJA were analyzed separately based on the guidelines of the ESCS (Mundy et al., 2003). No children were excluded from data analysis. Observations of specific behaviors which reflect IJA and RJA according to (Mundy et al., 2003) were recorded (counted) by two separate viewers. One viewer was a re-searcher in this study and the other was naive and blind to the study. Inraclass correlations coefficients were calculated for the two raters' scores based on the test type (pre and post) and joint attention type (IJA and RJA). The results are presented in the following format: average measures intraclass correlation (lower bound, upper bound). Pre-test IJA scores: 0.884 (0.706, 0.954), pre-test RJA scores: 0.853 (0.370, 0.952), post-test IJA scores: 0.862 (0.636, 0.946), and post-test RJA scores: 0.723 (0.305, 0.890). The scores of the two raters were then averaged and used in the statistical tests.

The following tests were conducted for IJA and RJA scores separately: 1. An independent samples t-test to see if the robot and control groups differed on their pre-test scores, 2. a paired samples t-test to see if the robot training group improved from pre to post-test, 3. a paired samples t-test to see if the control group improved from pre to post-test, 4. an independent samples t-test to see if the robot and control groups differed on their post-test scores.

Results

Test 1: the robot and control groups did not significantly differ on their pre-test scores for either IJA or RJA. Test 2: the robot training group did significantly improve from pre to post-test both on IJA and RJA. Test 3: the control group did not significantly improve from pre to post-test in either IJA or RJA. Test 4: the robot and control groups did not differ significantly on their post-test scores.

In Test 2 for IJA $t(9) = -3.11$, $p = 0.013$ with pre-test scores having a mean of 5.75 ($SD = 3.56$) and post-test scores having a mean of 11.15 ($SD = 4.96$) see Figure 5.2. For RJA $t(9) = -2.75$, $p = 0.023$ with pre-test scores having a mean of 159.17 ($SD = 49.14$) and post-test scores having a mean of 197.92 ($SD = 6.59$) see Figure 5.3.

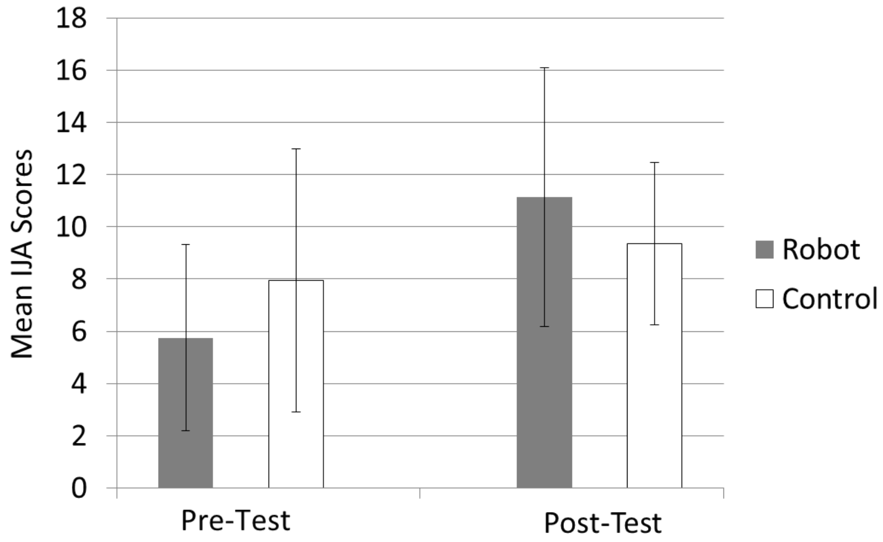


Figure 5.2: mean IJA scores are presented with standard divination bars for pre and post ESCS tests for both the robot treatment group (gray bars) and the control group (white bars). There is a significant difference between the pre and post-test scores of the robot treatment group, with children scoring higher in the post-test.

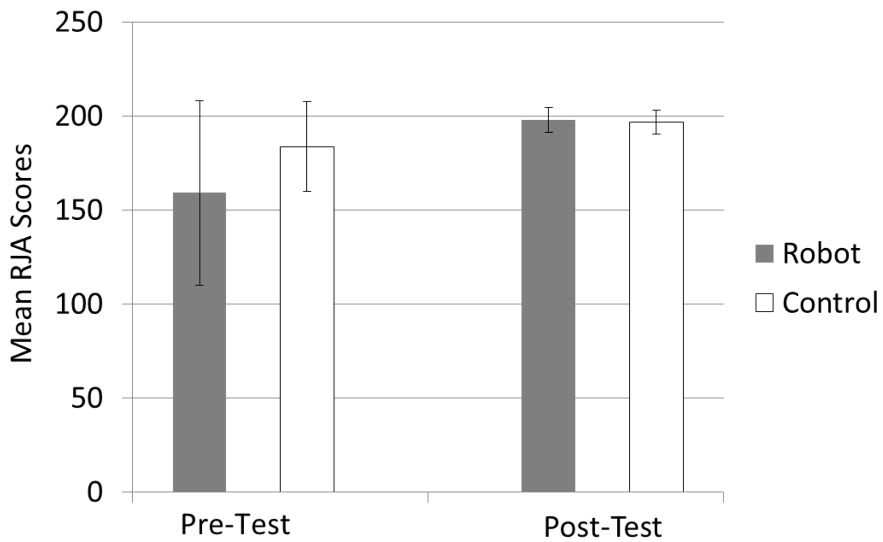


Figure 5.3: mean RJA scores are presented with standard divination bars for pre and post ESCS tests for both the robot treatment group (gray bars) and the control group (white bars). There is a significant difference between the pre and post-test scores of the robot treatment group, with children scoring higher in the post-test.

Discussion

The purpose of this study was to expand upon the research done by Kajopoulos, et al. (2015) where in a robot named "CuDDler" (A*Star) served to enhance the joint attention skills of Autistic children. The current study expanded on this previous work by introducing more sessions, testing more children, testing children from the whole spectrum of ASD, and comparing a robot treatment group with a control group. Based on Kajopoulos, et al. (2015) it was expected that the robot training group would show improvements in their ability to respond to joint attention (RJA), but not their ability to initiate joint attention (IJA). It was further hypothesized that the robot training group would show improvements in RJA skills, while the control group would not.

The current results show that the robot and control groups were not significantly different in their ability to IJA or their ability to RJA in the pre-test or the post-test. Furthermore, the control group showed no significant improvement from pre-test to post-test for IJA or RJA. However, the robot group showed a significant improvement from pre-test to post-test for both IJA and RJA. The results seen here replicate the results found by Kajopoulos, et al. (2015), in that RJA skills improved in the robot group. Additionally, these results showed an improvement in IJA, which Kajopoulos, et al. (2015) did not find. It is likely that this pattern was found for IJA in the current study, but not by Kajopoulos, et al. (2015) due to the increased sample size and in-creased variance of ASD in the participants. Furthermore, it is interesting that the two groups did not have a significant difference in their pre-test scores in either IJA or RJA, and although a significant change showing an increase in both IJA and RJA skills occurred in the robot treatment group, the post-test scores for the treatment group and control group were not significantly different in their IJA or RJA skills. So, even though there was a significant increase in the treatment group for both IJA and RJA, this change did not surpass the increase in scores for the control group.

If this issue is first looked at in IJA scores there was a child in the treatment group who had a score of zero, while in the control group the lowest score was two. Furthermore, the child who scored a zero in the pre-test then scored a 6.5 in the post-test after robot treatment. Whereas the child in the control group who scored two originally only had an improvement of two points (four in the post-test). This shows a case that although the two groups were not significantly different in the pre-test that since the sample size was small (only ten children per group) that the large variation shown by one participant may influence the data. This may be why the treatment group showed a significant improvement, but did not bi-pass the control group in post-test scores. This observation is however important as the child discussed here had mild-moderate ASD (also in the treatment group a child with moderate-sever showed large improvements) this may indicate that this type of therapy may be more beneficial for those children who are less functional.

This issue presents its self also in the RJA scores. As can be seen in Figure 5.3 the children in the treatment group had a larger SD in pre-test scores than the control group (however these groups were not significantly different in pre-test scores). The post-test SDs show a great reduction in SD form pre to post-test in the treatment group (the control group also shows a decrease, but not to the extent of the treatment group); in fact, in the post-test the two groups have similar SDs. Once again the fact that a significant increase is seen in the scores of the treatment group, but yet the treatment group does not surpass the scores of the control group in the post-test is likely due to variation of participants. The scores on this test are finite and range from 0-200. If the scores are binned into four groups (0-50, 50-100, 100-150, 150-200) two children in the treatment group during the pre-test scored in the bin of 50-100 (the other eight children scored in the 150-200 bin); while in the control group pre-test all children scored in the 150-200 bin. Therefore, the two children in the treatment group had greater room for improvement than the other participants. They did manage to show an improvement in their post-test by moving up to the 150-200 bin. So, once again this shows that although the two groups were not significantly different in the pre-test that since the sample size was small the large variation shown by one or two participants may influence the data. It is still important to note that these two children were the same children talked about in the IJA section who had moderate-sever and mild-moderate ASD. Once again, this may indicate that this type of therapy may be more beneficial for those children who are less functional.

In conclusion, it has been shown that robot therapy significantly increased the IJA and RJA skills of children with ASD. However, as their improvements did not surpass that of the control group one may ask if this is a beneficial therapy. The authors would argue that there has been proof of benefit here, especially in those children who are less functional. It would be beneficial if this study was repeated on a treatment and control group which consisted of children only in the lower levels of ASD and with a larger sample size.

Overall Conclusions

The first three studies (Chapters 2, 3, 4) presented in this dissertation were conducted to investigate the reason why in some studies action-perception links result in impairment effects and in other studies result in facilitation effects. Furthermore, how these impairment effects come about with real-world action plans was investigated. These chapters invested action and perception within a person, the final study (Chapter 5) took into consideration that action and perception do not only occur within a person, but often that in the real-world a person must interact with others and the environment around them. One social skill often used to achieve this goal is that of joint attention. Unfortunately, children with Autism Spectrum Disorder (ASD) often lack this skill; therefore it was investigated if a social robot, CuDDler (A*STAR), could be used to enhance the joint attention skills of children with ASD.

Results of Chapter 2 replicate the prior work by showing that planning of real-world actions can facilitate the detection of a target which shares dimensional properties with the action to be performed (Wykowska, Schubö, & Hommel, 2009; Wykowska, Hommel, & Schubö, 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012). Namely, size was considered a relevant dimension for grasping movements since, specification of size-related parameters is necessary to control grip aperture (Jeannerod, 1984; Milner & Goodale, 1995; Tucker & Ellis, 2001). Whereas, luminance was considered a relevant dimension for pointing movements because, during pointing movements luminance enables efficient localization of an object (Anderson & Yamagishi, 2000; Gegenfurtner, 2004; Graves, 1996).

Furthermore, Chapter 2 uses real-world action planning with a paradigm similar to Müsseler and Hommel (1997 a, b) in that a discrimination task performed on features of a target was used. This showed that when processing is required at the feature-level interference effects might be observed. Therefore, it seems that perhaps the reason why some studies find facilitation effects and others find impairments effects is due to the level at which perceptual processing is required, be it at the dimensional level or the feature level.

Results of Chapter 3 show that action-perception interference effects due to discrimination of features can be found not only in an attentional task (Carlson & Wykowska, in review, see Chapter 2), but also for a lower-level perceptual task which does not require attentional selection. Finally, Chapter 4, using the paradigm of Chapter 3, showed with ERP methodology that action-perception congruency (facilitation) effects related to dimensional processing may occur during early sensory processing (such as the time frame of the P1 component). However, it is not clear if action-perception interference (impairment) effects related to feature processing may occur during later processing (such as the time frame of the N1 component).

The final study (Chapter 5) moves from the lab to an applied setting where it was shown that a robot named “CuDDler” (A*Star) can be used as a tool to improve the joint attention skills (both initiating and responding to joint attention) of children with Autism Spectrum Disorder (ASD).

In summary, these chapters suggest that both intentional weighting and feature binding might occur during action planning and that action-perception congruency or interference effects are dependent on which level of perceptual processing is required (at the level of dimensions or features). It is suggested that processing at the level of dimensions can be done through the intentional weighting mechanism, which leads to congruency effects. While processing at the level of features might activate feature binding which leads to interference effects. Finally, was shown that a social robot may provide a unique and beneficial platform to improve the joint attention skills of children with ASD.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Anderson, S. J., & Yamagishi, N. (2000). Spatial localization of colour and luminance stimuli in human peripheral vision. *Vision Research, 40*, 759–771.

Bekkering, H., & Neggers, S.F.W, (2002). Visual search is modulated by action intentions. *Psychological Science, 13,* 370-374.

Cabibihan, J. J., Javed, H., Ang, M., Jr., & Aljunied, S. (2013). Why Robots? A Survey on the Roles and Benefits of Social Robots in the Therapy of Children with Autism. *International Journal of Social Robotics, 5*(4), 593-618. doi: 10.1007/s12369-013-0202-2

Carlson, K., & Wykowska, A. (in review) The Intentional Weighting Mechanism: Perceptual Dimensions Versus Features. *Journal of Cognitive Psychology*.

Charman, T. (2003). Why is joint attention a pivotal skill in autism? Philosophical Transactions of the Royal Society of London. Series B: *Biological Sciences, 358*(1430), 315-324. doi: 10.1098/rstb.2002.1199

Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus & Masson's method. Tutorials in Quantitative Methods for Psychology, 1, 42–45.

Craighero, L., Fadiga, L., Rizzolatti, G., Umiltà, C., A. (1999). Action for perception: a motor-visual attentional effect. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 1673-1692.

Dautenhahn, K. (2003). Roles and functions of robots in human society: implications from research in autism therapy. *Robotica, 21*(04), 443-452. doi:10.1017/S0263574703004922

Elliott, D., Helsen, W. F., & Chua, R. (2001). A century later: Woodworth's (1899) two-component model of goal-directed aiming. *Psychological Bulletin, 127*, 342–357. doi:10.1037/0033-2909.127.3.342

Fagioli, S., Hommel, B., & Schubotz, R.I. (2007). Intentional control of attention: Action planning primes action-related stimulus dimensions. *Psychological Research, 71*, 22-29.

Found, A., & Müller, H. J. (1996). Searching for unknown feature targets on more than one dimension: Investigating a 'dimension weighting' account. *Perception & Psychophysics, 58*, 88-101.

Gegenfurtner, K. R. (2004). The accuracy of pointing movements to targets defined by color [Abstract]. *Journal of Vision, 4*, 404a.

Gordon, R.M. & Cruz, J. (2002). In L. Nagel (ed.), *Encyclopedia of Cognitive Science*. Macmillan.

Graves, R. E. (1996). Luminance and colour effects on localization of briefly flashed visual stimuli. *Visual Neuroscience, 13*, 567–573.

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences, 24*, 849-878.

Hommel, B. (2004). Event files: Feature binding in and across perception and action. *Trends in Cognitive Sciences, 8*, 494-500.

Hommel, B. (2010). Grounding attention in action control: The intentional control of selection. In B.J. Bruya (ed.), *Effortless attention: A new perspective in the cognitive science of attention and action* (pp. 121-140). Cambridge, MA: MIT Press.

Jeannerod, M. (1984). The timing of natural prehension movements. *Journal of Motor Behavior*, *16*, 235–254.

Kahneman, D. & Treisman, A. (1984). Changing views of attention and automaticity. In Parasuraman, R. & Davies, D.R. (Eds), *Varieties of attention* (pp. 29-61). New Work: Academic Press.

Kajopoulos, J. (2014). Using socially assistive robotics to enhance joint attention learning for children with autism spectrum disorder (Unpublished Master's thesis). Ludwig Maximilians Universität, München, Germany.

Kajopoulos, J., Wong A.h.Y., Zuen, A.W.C., Dung, T. A., Tan, Y. K., Wykowska, A. (2105). Robot-assisted training of joint attention skills in children diagnosed with autism. Accepted for presentation at ICSR 2015, to be published in LNAI 2015.

Keysers C. & Gazzola, V. (2007). Integrating simulation and theory of mind: from self to social cognition. Trends in Cognitive Sciences. 11 (5): 192–194.

Kumada, T. (2001). Feature-based control of attention: Evidence for two forms of dimension weighting. *Perception & Psychophysics, 63* (4), 698-708.

Leekam, S. R., López, B., & Moore, C. (2000). Attention and joint attention in preschool children with autism. *Developmental Psychology, 36*(2), 261-273. doi: 10.1037/0012-1649.36.2.261

Luck, S. J., Fan, S., and Hillyard, S. A. (1993). Attention-related modulation of sensory-evoked brain activity in a visual search task. *J. Cogn. Neurosci.* 5, 188–195.

Luck, S. J., and Hillyard, S. A. (1995). The role of attention in feature detection and conjunction discrimination: an electrophysiological analysis. *Int. J. Neurosci.* 80, 281–297.

Meindl, J., & Cannella-Malone, H. (2011). Initiating and responding to joint attention bids in children with autism: A review of the literature. *Research in Developmental Disabilities, 32*(5), 1441-1454. doi: http://dx.doi.org/10.1016/j.ridd.2011.02.013

Memelink, J. & Hommel, B. (2013) Intentional weighting: a basic principle in cognitive control. *Psychological Research*, 77:249–259. DOI 10.1007/s00426-012-0435-y

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action*. Oxford, England: Oxford University Press.

Molenberghs P., Cunnington R., Mattingley J. (2009). Is the mirror neuron system involved in imitation? A short review and meta-analysis. *Neuroscience & Biobehavioral Reviews*. 33 (1): 975–980. doi:10.1016/j.neubiorev.2009.03.010.

Moore, C., & Dunham, P., J. (2014). *Joint Attention: Its Origins and Role in Development*. New York: Psychology Press.

Müller, H. J., Krummenacher, K., Geyer, T., & Zehetleitner, M. (2009). Attentional capture by salient color singleton distractors is modulated by top-down dimensional set. *Journal of Experimental Psychology: Human Perception and Performance*, 35, 1–16.

Mundy, P. & Crowson, M. (1997). Joint Attention and Early Social Communication; Implications for Research on Intervention with Autism. *Journal of Autism and Developmental Disorders, 27* (6), 653-676.

Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). *A Manual for the Abridged Early Social Communication Scale (ESCS).*

Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. *J Autism Dev Disord, 20*(1), 115-128.

Müsseler, J., & Hommel, B. (1997a). Blindness to response-compatible stimuli. *Journal of Experimental Psychology: Human Perception and Performance, 23*, 861-872.

Müsseler, J., & Hommel, B. (1997b). Detecting and identifying response-compatible stimuli. *Psychonomic Bulletin & Review*, 4, 125-129.

Prinz, W. (1987). "Ideo-motor action," in *Perspectives on Perception and Action*, eds H. Heuer, and A. F. Sanders (Hillsdale: Erlbaum), 47–76.

Prinz, W. (1997). Perception and action planning. *Eur. J. Cogn. Psychol.* 9, 129–154.

Rizzolatti, G. & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*. 27 (1): 169–192. doi:10.1146/annurev.neuro.27.070203.144230.

Sagi & Julesz (1985) Detection versus Discrimination of Visual Orientation. *Perception, 14*, 619-628.

Scassellati, B., Admoni, H., & Matarić, M. (2012). Robots for Use in Autism Research. *Annual Review of Biomedical Engineering, 14*(1), 275-294. doi: doi:10.1146/annurev-bioeng-071811-150036

Taylor, B. A., & Hoch, H. (2008). Teaching children with autism to respond to and initiate bids for joint attention. *Journal of Applied Behavior Analysis*, 41(3), 377-391. doi: 10.1901/jaba.2008.41-377

Taylor, M. (2002). Non-spatial attentional effects on P1. *Clinical Neurophysiology*, 113, 1903–1908.

Treisman, A., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology,* 12, 97-136.

Treisman, A. and Gormican, S. (1988). Feature Analysis in Early Vision: Evidence From Search Asymmetries. *Psychological Review*, 95(1), 15-48.

Tucker, R., & Ellis, M. (2001). The potentiation of grasp types during visual object categorization. *Visual Cognition, 8,* 769–800.

Uddin, L. Q., Iacoboni, M., Lange, C., Keenan, J. P. (2007). The self and social cognition: the role of cortical midline structures and mirror neurons. Trends in Cognitive Sciences. 11 (4): 153–157.

Vogel, E. & Steven, L. (2000). The visual N1 component as an index of a discrimination process. *Psychophysiology, 37*, 190–203.

Whalen, C., & Schreibman, L. (2003). Joint attention training for children with autism using behavior modification procedures. *Journal of Child Psychology and Psychiatry, 44*(3), 456-468. doi: 10.1111/1469-7610.00135

Wolfe & Bennett (1997) Preattentive Object Files Shapeless Bundles of Basic Features. *Vision Res., 37*(1), 25-43.

Woodworth, R. S. (1899). The accuracy of voluntary movement. *Psychological Review, 3,* (3, Suppl. 13), 1-119.

Wykowska, A., Hommel, B., and Schubö, A. (2011). Action-induced effects on perception depend neither on element-level nor on setlevel similarity between stimulus and response sets. *Atten. Percept. Psychophys., 73,* 1034–1041.

Wykowska, A., Hommel, B., Schubö, A. (2012). Imaging when acting: picture but not word cues induce action-related biases of visual attention. *Frontiers in Psychology*, 3:388.

Wykowska, A., Schubö, A., and Hommel, B. (2009). How you move is what you see: action planning biases selection in visual search. *J. Exp. Psychol. Hum. Percept. Perform., 35,* 1755–1769.

Wykowska, A., Schubö, A. (2012). Action intentions modulate allocation of visual attention: electrophysiological evidence. *Frontiers in Psychology*, 3: 379.

Zhang,W., and Luck, S. (2009). Feature based attention modulates feedforward visual processing. *Nat. Neurosci.* 12, 24–25.

Appendix

Appendix I A

Combination	Left Side of Screen	Right Side of Screen
light & small	Disk A	Disk A
light & large	Disk B	Disk B
dark & small	Disk C	Disk C
dark & large	Disk D	Disk D

SET 1: Both disks same in luminance & size. The “combination” column indicates the features the two circles consisted of. The “left side of screen” column indicates that the circle in that paring was presented on the left side of the asterisk. The “right side of screen” column indicates that the circle in that paring was presented on the right side of the asterisk.

Appendix I B

Combination	Left Side of Screen	Right Side of Screen
light small & dark small	 Disk A	 Disk C
dark small & light small	 Disk C	 Disk A
light large & dark large	 Disk B	 Disk D
dark large & light large	 Disk D	 Disk B

SET 2: Luminance different & size same. The “combination” column indicates the features the two circles consisted of. The “left side of screen” column indicates that the circle in that paring was presented on the left side of the asterisk. The “right side of screen” column indicates that the circle in that paring was presented on the right side of the asterisk.

Appendix I C

Combination	**Left Side of Screen**	**Right Side of Screen**
Light small & light large	 Disk A	 Disk B
Light large & light small	 Disk B	 Disk A
Dark small & dark large	 Disk C	 Disk D
Dark large & dark small	 Disk D	 Disk C

SET 3: Luminance same & size different. The “combination” column indicates the features the two circles consisted of. The “left side of screen” column indicates that the circle in that paring was presented on the left side of the asterisk. The “right side of screen” column indicates that the circle in that paring was presented on the right side of the asterisk.

Appendix 2

Mean hit rates and false alarm rates in Experiment 1

Relevant Dimension	Movement	Mean Hit Rate	Mean False Alarm Rate
Luminance	Grasp	0.90	0.18
	Point	0.89	0.20
Size	Grasp	0.89	0.09
	Point	0.90	0.07

Deutsche Zusammenfassung

Theoretischer Hintergrund

Die Theorie der Event Coding (TEC) Vorschlag Hommel, Müsseler, Aschersleben, und Prinz (2001) deuten darauf hin dass Wahrnehmung und Handlungen eine gemeinsame repräsentative Domäne teilen, ermöglicht so eine bidirektionale Verbindung zwischen den beiden Prozessen. Allerdings sind diese bidirektionale Aktion Wahrnehmung bei Untersuchung Links hat es sich gezeigt dass Maßnahmen in einigen Fällen kann **beeinträchtigen** die Wahrnehmung der aktions kongruent Reize (Müsseler und Hommel, 1997 a, b), während in anderen Fällen können Aktionen **erleichtern** die Wahrnehmung von aktions kongruent Reize (Wykowska, Schubö & Hommel, 2009; Wykowska, Hommel, & Schubö 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012).

Wenn man einen genaueren Blick auf diese Paradigmen nimmt er kennen, dass in den Studien von gesehen worden (Müsseler und Hommel, 1997 a, b) die Aktion-Plan Komponente bestand aus linken oder rechten Taste drückt, dass der Aktionsplan mit dem Wahrnehmungs überlappt Reiz in Bezug auf Merkmale (links oder rechts), und dass Teilnehmer eine Diskriminierung Aufgabe auf dem Wahrnehmungsreiz durchgeführt. In den Studien von (Wykowska, Schubö & Hommel, 2009; Wykowska, Hommel, & Schubö 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012) die Action-Plan Komponente bestand ausrealen Welt Aktionen (Greifen oder Zeige), überlappt die Aktion-Plan mit dem Wahrnehmungsreiz in Bezug auf Dimensionen und die Wahrnehmungs Aufgabe Teilnehmer benötigt eine Erkennung Aufgabe für ein Ziel in einem Such Array auszuführen.

die Vorsätzliche Gewichtung Mechanism (IWM) Vorschlag (Hommel et al ,2001;. Wykowska et al, 2009; Memelink & Hommel, 2013) versucht zu erklären wie Wahrnehmung und Handlung durch einen gemeinsamen Code Wechsel wirkung treten können. Dieser gemeinsame Code wird angenommen zu verknüpfen aktiv erzeugt Ereignisse und wahrgenommen Ereignisse in dem die sensorischen Komponenten der beiden Prozesse halten. Diese gemeinsamen Codes gedacht werden um während Maßnahmenplanung gebildet werden und bestehen aus episodischen Gedächtnisspuren oder **Ereignisdateien** (Hommel, 2004). Event Dateien ähnlich wie ein Konzept vorgeschlagen von sind Wolfe & Bennett (1997) die vorge aufmerksam "Objektdateien" diskutieren die von unförmigen Bündel von grundlegenden Funktionen bestehen.

Weiteren wird vorgeschlagen dass bei Planung einer Aktion die Reize die Aktie Dimensionen mit der geplante Aktion sind ein höheres Gewicht und damit verarbeitet vorrangig aufgrund ihrer Relevanz für spätere Online Anpassung der Handlungssteuerung gegeben. Allerdings ist die IWM nicht die Frage der Handlungswahrnehmung Beeinträchtigung Adresse von (Müsseler und Hommel, 1997 a, b)gefunden.

Der erste Teil dieser Arbeit (Kapitel 2, 3, 4) verwendet eine modifizierte Version der experimentellen Paradigmen Wykowska et al. (2009 und Wykowska et al. (2011) Wertminderung und Erleichterung Effekte im Zusammenhang der realen Welt Aktionen zu untersuchen. Kapitel 2 richtet beide Arten von Effekten mit realen Aktionen zu untersuchen. Aufgabe eines untersucht wie realen Welt Aktionen Wirkung Wahrnehmungs Verarbeitung wenn Wahrnehmungserkennung erforderlich ist. Aufgabe zwei sucht wie reale Aktionen Wahrnehmungsverarbeitung bewirken wenn Wahrnehmungs Diskriminierung erforderlich ist. Ergebnisse dieser Aufgaben (Wahrnehmungs Erkennung und Diskriminierung) verglichen. Kapitel 3 auch untersucht wie realen Welt Aktionen Wirkung Wahrnehmungs verarbeitung wenn Wahrnehmungs Diskriminierung erforderlich. anstatt jedoch eine Aufgabe, die visuelle Aufmerksamkeit (eine visuelle Suchaufgabe, wie in verbunden Wykowska et al., 2009) ist, Teilnehmer eine Aufgabe durchgeführt die nur Verarbeitung von Reizen Merkmale und nicht attentional Auswahl erforderlich. Kapitel 4 verwendet das Paradigma von Kapitel 3 mit dem Zusatz von ERP Methodik. Diesem Kapitel Verwendung ERP Methodik Ziel zu untersuchen wie die Planung Maßnahmen die verschiedenen Stadien der Wahrnehmungsverarbeitung in einer Feature -Unterscheidungsaufgabe erforderlich beeinflussen können.

Der zweite Teil der Arbeit (Kapitel 5) zielt darauf ab von Untersuchung Aktion und Wahrnehmung im Labor zu bewegen um Anwendung Wissen von Handlung und Wahrnehmung in einer realen Umgebung. Hierzu ein Ziel Roboter "CuDDler" genannt (A * Star) wurde getestet um zu sehen ob es die Fähigkeit hatte die gemeinsame Aufmerksamkeit Fähigkeiten von Kindern mit Autismus Spektrum Störung zu verbessern.

Übersicht über die Experimente in der vorliegenden Dissertation

der intentionale Gewichtung Mechanismus Perceptual Abmessungen gegen Merkmale

Kapitel 2 beschreibt zwei Aufgaben die die Wirkung der Planung einer realen Aktion (Greifen oder Zeige) auf Wahrnehmungsverarbeitung entweder einer Detektionsaufgabe untersuchen die Wahrnehmungsverarbeitung auf der Dimensionsebene erforderlich (hier Dimension = Größe) oder eine Unterscheidungsaufgabe Wahrnehmungsverarbeitung auf der Funktionsebene erfordern (klein oder groß). Dies wurde getan untersuchen wie die Differenz in Wahrnehmung Aufgabe zu Beeinträchtigung oder Erleichterung der führen kann Wahrnehmung der aktions kongruent Reizemit realen Aktionen.

In den ersten Aufgabe Teilnehmer wurden trial-by-trial informiert wenn sie entweder einen Greifdurchführen soll oder Zeigebewegung unter dem Computer Bildschirm zu einem Pappbecher später ausgeführt werden. Nachdem die Bewegung cued planen sie mit einer Erkennungsaufgabe vorgestellt wurden wobei sie war unter 27 anderen Kreisen vorhanden oder nicht vorhanden wenn eine Größe Ziel zu erfassen hatte. In der zweiten Aufgabe wurde die Detektionsaufgabe zu einer Unterscheidungsaufgabe geändert. Hier Teilnehmer zu bestimmen hatte wenn die Größe Ziel klein oder groß war.

Vergleich von RTs auf die Faktoren Aufgabentyp (Erkennung vs. Diskriminierung) und Bewegungsart (Greifen vs. Zeige) zeigte einen Haupteffekt der Aufgabentyp und interessanter eine Interaktion zwischen die Faktoren. Der Haupteffekt der Aufgabentyp zeigten Teilnehmer schneller in der Unterscheidungsaufgabe ist als die Detektionsaufgabe. Dieses einfach auf die Tatsache zurückzuführen sein, dass die Unterscheidungsaufgabe am zweiten Tag durchgeführt wurde, und daher die Teilnehmer mit der Aufgabemehr Erfahrung hatte.

Die Wirkung von Interesse zeigte die Interaktion zwischen Aufgabentyp und Bewegungsartdass bei der Erkennung Aufgabewenn Teilnehmer vorbereitet Bewegung ein Greif sie waren geringfügig schneller eine Größe Ziel als zu erkennen wenn sie eine Zeigebewegung vorbereitet hatte. In der Unterscheidungs Aufgabe wenn Teilnehmer eine Zeigebewegung vorbereitet waren sie wesentlich schneller der Größe eines Ziel als zu unterscheiden wenn sie eine Greifbewegung vorbereitet hatte.

Die Ergebnisse der Detektionsaufgabe zeigen die typische Erleichterung (Kongruenz Effekt) durch andere Studien zuvor gesehen (Wykowska, Schubö & Hommel, 2009; Wykowska, Hommel, & Schubö 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012)a. Während die Ergebnisse der Unterscheidungsaufgabe zeigen Interferenzeffekte ähnlich wie Müsseler und Hommel (1997 a,b),aber jetzt mit realen Aktionen. In Summe legen diese Ergebnisse nahe dass wenn die Aufgabe auf der Ebene der Dimensionen, handlungsbezogene Vorurteile der Wahrnehmungsverarbeitung Wahrnehmungs Verarbeitung erfordert Effekte in Form von Erleichterung beobachtet werden können (Kongruenz). Wenn jedoch die Aufgabe auf der Ebene der Merkmale, handlungsbezogene Vorurteile der Wahrnehmungsverarbeitung Wahrnehmungs Verarbeitung benötigtkann in Form von Interferenzeffekte beobachtet werden. Diese Ergebnisse geben einen Einblick in die verschiedenen Muster der Ergebnisse in verschiedenen Paradigmen action Wahrnehmung Links zeigt.

Die Rolle der Merkmale Diskriminierung in Aktion Wahrnehmung Interferenzeffekte

Kapitel 3 beschreibt ein Experiment entworfen um die Diskriminierung Rolle Funktion untersuchen spielt in Aktion Wahrnehmung Störungen Auswirkungen. Das derzeitige Paradigma versucht diese Aktion Wahrnehmung Verzerrungen in Feature-basierte Verarbeitung zu zeigen, bevor in einem Aufmerksamkeits Aufgabe gesehen(Carlson& Wykowska, in Überprüfung, siehe Kapitel 2), kann auf eine niedrigere Ebene Wahrnehmungs Aufgabe verallgemeinert werden wo attentional Auswahl ist. Nicht erforderlich

dieses Experiment Teilnehmer wurden blockweise informiert wenn sie diskriminieren sollten wenn zwei Platten gleich oder verschieden entweder Luminanz oder Größe Merkmalswerte waren. Wieder wurden informierte Teilnehmer bei jedem Versuch zufällig wenn sie ein Zeige oder Greifbewegung ausgeführt werden nachdem die Unterscheidungsaufgabe planen sollte.

Entweder physisch oder verschieden sein könnte Die Scheiben vorgestellt auf der irrelevanten Dimension (beide die gleiche Größe und Helligkeit) (für Beispiel in der Größe Blöcke Stimuli die die gleiche Größe waren, aber unterschiedliche Luminanz) beide dieser Satztypen erforderlich eine Antwort von "gleich" da sie die gleiche auf der entsprechenden Dimension waren. Der dritte Satz Typ unter schied auf der entsprechenden Dimension und die gleiche auf der irrelevant Dimension (beispielsweise in der Größe Blöcke Stimuli die von unterschiedlicher Größe sind, aber gleiche Luminanz) dieser Satz eine Antwort von "anderen" erforderlich. Da die beiden "gleiche" Set Typen unterschiedliche Signale erzeugt wurden sie getrennt analysiert. In beiden Analysen wurden d-Primzahlen verwendet der Teilnehmer Empfindlichkeit der Differenz zwischen den Scheiben zu messen.

In der ersten Analyse identisch "gleich" und "anders" setzt d-Primzahlen wurden verwendet zu berechnen. In dieser Analyse wurde ein Haupteffekt der Dimension mit Größe Hervorrufen einer größeren d-prime als Leuchtdichte gefunden. Dieses Ergebnis ist meistens wahrscheinlich aufgrund der Größe Blöcke ist einfacher als Luminanz Blöcke. Auch eine signifikante Wechselwirkung zwischen Dimension (Luminanz vs. Größe) und Bewegungsart (Greifen vs. Zeige) gefunden. Dabei zeigte dass Diskriminierung Teilnehmerhöhere Empfindlichkeit der Differenz während Luminanz hatten als sie einen Greifbewegung relativ zu zeigen vorbereitet hatte. Während bei Größe hatte Diskriminierung Teilnehmerhöhere Empfindlichkeit auf den Unterschied wenn sie eine Zeigebewegung vorbereitet hatte, relativ zu erfassen. In der zweiten Analyse irrelevant-Dimension "gleich" und "anders" Sets wurden verwendet-Primzahlen zu berechnen. Diese Analyse zeigte nur einen signifikanten Haupteffekt der relevanten Dimension mit Größe einen größeren d-prime als Leuchtdichte hervorrufen. Dies könnte darauf hindeuten dass die irrelevante Dimension noch einigermaßen verarbeitet wurde und somit könnten die Effekte aus storniert haben.

Diese Ergebnisse unterstützen die Idee dass Aktionswahrnehmung Interferenzeffekte treten wenn merkmalsbasierte Verarbeitung erforderlich ist (Carlson & Wykowska, in Überprüfung, siehe Kapitel 2).Die vorliegende Studie erweitert die bisherigen Erkenntnisse durchzeigen dass die Aktion Wahrnehmung Verzerrungen in Feature-basierte Verarbeitung von einer Aufmerksamkeits Aufgabe zu einem untergeordneten Wahrnehmungs Aufgabe verallgemeinern wo attentional Auswahl ist nicht erforderlich.

Die Rolle der Feature Diskriminierung in Aktion Wahrnehmung Interferenz Effekte: ein EEG Studie

Kapitel 4 das gleiche Paradigma Kapitel 3verwendet (Kapitel 3) mit dem Zusatz von .Elektroenzephalographie (EEG) Wykowska & Schubö (2012) festgestellt dass wenn

Teilnehmer hatten ein Greifen oder Zeige vorzubereiten Bewegung erfassen dann ein Ziel auf Grundlage seiner Dimension entweder Größe oder Luminanz (blockweise), dass es in dem Luminanz Zustand eine verbesserte Positivität in P1 über die occipitalen Elektroden (O1 / O2 und PO7 / PO8) war als eine Zeige Bewegung wurde hergestellt Bezug auf wenn eine Greifbewegung vorbereitet wurde. Keine signifikanten Effekte wurden in der Größe Zustand gefunden. Daher wurde angenommen dass in der aktuellen Paradigma vorge selektive Gewichtung der Dimensionen mit einem Muster reflektiert werden würde die Aktion Wahrnehmung Erleichterung (Kongruenz) Effekte in P1 (wie Wykowska & Schubö, 2012)unterstützt.

Da jedoch der Vergleich Aufgabe erforderliche Unterscheidung der Merkmale der Reize wurde angenommen dass spätere Verarbeitung um die Zeit der N1Komponente würde Aktion Wahrnehmung Interferenzeffekte widerspiegeln. Diese Komponente war von Interesseweil, Vogel & Luck (2000) dass die inferoposterior Komponente 140 mit seiner Spitzenamplitude gezeigt haben - 180 ms nach dem Stimulus an seitlichen Hinterhaupts Elektroden möglicherweise Diskriminierung spiegeln könnten.

Wieder die Scheiben in drei verschiedenen Sätzen dargestellt werden 1 . identisch - "gleich", 2. gleiche relevante Dimension, andere irrelevant Dimension - "gleich" oder 3. andere relevante Dimension, gleiche irrelevant Dimension - "anders". Aufgrund einer Differenz im Testtypnummer pro Zustand (Größe oder Luminanz) wurden Bedingungen getrennt und durch Versuch Typ analysiert. Damit für jede Bedingung (Größe oder Luminanz) ANOVAs auf Bewegungsart durchgeführt wurden (Greifen vs. Zeige) und Elektrode. Schließlich wurden die Faktoren Zustand (Größe vs. Luminanz), Bewegungsart (Greifen gegen Zeige) und Elektrode Vergleich zu den gleichen -."gleich" Studien

140 ms nach dem Stimulus an den Elektroden-Die P1Komponente wurde 80 analysiert O1, O2, PO7, PO8.In der Größe Zustand auf den gleichen Studien gab es einen Haupteffekt

der Bewegung mit Greif eine verbesserte Positivität mit als zeigen. Im Vergleich der Bedingung, Bewegungsart und Elektrodenstelle gab es einen Haupteffekt der Bedingung mit Größe eine verbesserte Positivität als Leuchtdichte und eine Wechselwirkung von Zustand und Bewegung haben. Beide zeigen under fassen waren deutlich positiv in der Größe Zustand im Vergleich zu dem Helligkeits Zustand verbessert. Darüber hinaus innerhalb der Größe Zustand eine verbesserte Positivität als Hinweis hatte er fassen.

Die verbesserte Positivität für die Größe Zustand Vergleich zu dem Helligkeits Zustand allein die Tatsache widerspiegeln, dass es leichter war zu bestimmen ob die Kreise die gleiche Größe waren, als es war, festzustellen ob sie die gleiche Leuchtdichte waren. Eine Modulation der P1Komponente mit Greif eine verbesserte Positivität relativ aufweist in der Größe Zustand zu zeigen scheint Wirkung Wahrnehmung Kongruenz Effekte zu reflektieren. Dieser Nachweis kann sein dass dimensionale Gewichtungseffekte sensorischen P1Komponente die frühen beeinflussen können (80-140 ms), daß Dimensionen die mit Priorität bearbeitet werden sollen und sind deckungsgleich mit der Aufgabe in Hand kann Modifikation dieser frühen sensorischen Komponente führen.

Die 200 ms Post-Stimulus an den Elektroden- N1 Komponente wurde 160analysiert. O1, O2, PO7, PO8,P7 und P8.In die Größe Zustand auf den anderen Größe Studien ein Haupteffekt war mitzeigen negativer ist als Greif Man kann zunächst wollen dies zu interpretieren als Handlings Wahrnehmung Interferenzeffekte, aber in der Größe Zustand auf den verschiedenen Größen Studien zeigen war schneller als in RTs erfassen, so dass diese ERP Effekt sein könnte einer der Zeige insgesamt erfordern weniger kognitive Ressourcen als erfassen. Deshalb in dieser Studie ist es wahrscheinlich dass Teilnehmer über ausgebildete wegen all der Praxis geworden sind, was die Planung von fast automatisiert werden zeigen und die weniger kognitive Ressourcen.

Abschließend diese Ergebnisse das frühe sensorische Prozess kann zu zeigen scheinen durch die Kongruenz einer Aktion mit einer Aufgabe relevanten Dimension beeinflusst werden. Es ist jedoch noch nicht klar wie spät Verarbeitung, nämlich Diskriminierung von Merkmalen, eine Rolle bei Aktion Wahrnehmung Interferenzeffekte hat. Es kann klug sein eine EEG Untersuchung durch zu führen diese Effekte in einem Paradigma ähnlich wie zu (Carlson & Wykowska, in Überprüfung, siehe Kapitel 2)untersuchen.

Verbesserung Joint Aufmerksamkeit Fähigkeiten bei autistischen Kindern über einen Roboter

Kapitel 5 Adressenwie Wissen im Labor gewonnen zu verwenden in angewandten realen. In diesem Experimente in Roboter namens "HuGGler" (A * Star) diente dazu die gemeinsame Aufmerksamkeit (JA) Fähigkeiten von Kindern mit Autismus Spektrum Störung zu verbessern. Innerhalb JA gibt es zwei Mechanismen. Eine die Funktionen gemeinsame Aufmerksamkeit (IJA) einzuleiten; zB ein Objekt auf andere zeigt; und eine Funktionen, die gemeinsame Aufmerksamkeit (RJA) zu reagieren; zB den Kopf drehen in Richtung zu suchen die andere Person zeigt und schaut (Mundy & Crowson,1997).Die Idee war das in dem Sie den Blick des Roboters triggern die JA Fähigkeiten der Kinder verbessern würde. Zwei Gruppen von Kindern mit Asperger Syndrom getestet wurden, eine Gruppe erhielt Roboter Behandlung und die andere Gruppe diente als Kontrollgruppe. Beide Gruppen "JA Fähigkeiten wurden bereits getestet und nach experimentellen Sitzungen (Roboter Behandlung oder Kontrolle Sitzungen) mit dem gekürzten frühen sozialen Kommunikations Skala, ESCS (Mundy, Delgado, Block, Venezia, Hogan & Seibert, 2003).

Roboter Behandlung bestand aus einem Trainingseinheit die Kinder mit der Aufgabe vertraut zu machen, und dann 8 Sitzungen von ca. 10 Minuten über einen Zeitraum von 4 Wochen (2 Sitzungen pro Woche) durchgeführt. Kinder in der Kontrollgruppe erhielt die gleiche Menge an Sitzungen, aber sie spielten mit einem Teddybären oder anderes Spielzeug in dieser Zeit statt mit dem Roboter zu interagieren. In den Roboterbehandlungssitzungen der Roboter "gesucht" an einem von zwei Bildern gleichzeitig auf zwei Telefon Bildschirmen präsentiert platziert links und rechts des Roboters. Die Aufgabe des Kindes war verbal die Farbe des Bildes zu berichtender Roboter wurde "Suche" an.

Das Scoring System für den ESCS (Mundy et al., 2003) wurde vom Experimentator verwendet und auch ein unabhängiger Programmierer, zu fällig war naiv zu das Experiment. Interclass Korrelationskoeffizienten wurden zwischen den Werten der beiden Rater berechnet. Diese Ergebnisse zeigten dass die Ergebnisse hoch und damit korrelieren, wurden die Ergebnisse zusammen gemittelt bevor sie statistische Tests vorgelegt. Ergebnisse der beiden Typen von JA (IJA und RJA) wurden getrennt analysiert.

Ergebnisse zeigten dass die Gruppen auf ihren Pre-Test noch Post-Test basiert auf entweder IJA oder RJA nicht signifikant verschieden waren. Die Partituren Roboterbehandlungsgruppe sowohl für IJA und RJA signifikant von Pre-Test auf Post-Test verbessert; während die Kontrollgruppe nicht. Da die Behandlung und Kontrolle nicht signifikant auf post-Testwerte unterschieden sich waren die Daten weitersuchen, darauf hindeutet dass obwohl die Gruppen auf ihren Pre-Test Partituren nicht signifikant unterschiedlich warendass die Behandlungsgruppe enthielt zwei Kinder mit mehr ASD trennen. Es scheint dass diese Kinder die Erhöhung der Werte von prä- zu post-Test gefahren haben. Diese Ergebnisse zeigen dass Roboter Therapie verwendet werden können die JA Fähigkeiten von Kindern mit ASD zu verbessern und kann am vorteilhaftesten für die Kinder in der milden mittelschwerer bis mäßig-Sever Bereich des Spektrums.

Schlussfolgerungen

Die ersten drei Studien (Kapitel 2, 3 wurden, 4 in dieser Dissertation vorgelegt) durchgeführt der Grundwarum in einigen Studien Aktion Wahrnehmung Links führen einer

Beeinträchtigung Effekte und in anderen Studien ergeben Erleichterung Effekte zu untersuchen. Darüber hinaus wie diese Beeinträchtigung Effekte kommen mit realen Aktionspläne untersucht. Die letzte Studie (Kapitel 5) bewegt sich aus dem Labor in die reale Einstellung der Erziehung Kindern mit Autismus Spektrum Störung gemeinsame Aufmerksamkeit Fähigkeiten über einen Roboter.

Ergebnisse des Kapitels 2 replizieren die früheren Arbeiten durch das Planung der realen Welt zeigen Aktionen können die Erkennung eines Ziels erleichtern die durchgeführt werden dreidimensionale Objekte mit der Aktion Aktien (Wykowska, Schubö & Hommel, 2009; Wykowska, Hommel, & Schubö 2011; Wykowska, Hommel, & Schubö 2012; Wykowska & Schubö 2012).heißt, Größe eine relevante Dimension für Greif Bewegungen da Spezifikation von größenabhängigen Parameter ist notwendig umsteuern Griff Öffnung betrachtet (Jeannerod 1984; Milner & Goodale, 1995; Tucker & Ellis, 2001)wurde. Während wurde Luminanz ein relevant betrachtet Dimension für Zeige Bewegungen da während Zeigebewegungen Luminanz effiziente Lokalisierung eines Objektsermöglicht. (Anderson & Yamagishi, 2000; Gegenfurtner, 2004; Graves, 1996)

Darüber hinaus Kapitel 2 verwendet realen Aktionsplanung mit einem Paradigma ähnlich wie Müsseler und Hommel (1997 a, b),dass eine Unterscheidungsaufgabe auf Merkmale eines Target verwendet wurde durchgeführt. Dies zeigte dass bei Verarbeitung an den Funktionsebene Interferenzeffekte erforderlich ist kann beobachtet werden. Daher scheint es das vielleicht der Grundwarum einige Studien Erleichterung Effekte finden und andere finden Beeinträchtigungen Auswirkungen auf das Niveau zurückzuführen ist bei der Wahrnehmungsverarbeitung erforderlich ist, sei es auf der dimensionalen Ebene oder Merkmalsebene.

Ergebnisse zeigen Kapitel 3die aktions Wahrnehmung Interferenzeffekte aufgrund Diskriminierung von Merkmalen kann nicht nur in einer Aufmerksamkeits Aufgabe gefunden werden(Carlson& Wykowska, in Überprüfung, siehe Kapitel 2), sondern auch für eine niedrigere Ebene Wahrnehmungs Aufgabe die nicht attentional Auswahl erfordert. Schließlich 4 Kapitel, das Paradigma des Kapitels mit 3 zeigte mit ERP Methodikdie Aktion Wahrnehmung Kongruenz (Erleichterung) zu dreidimensionalen Verarbeitung bedingte Effekte während frühen sensorischen Verarbeitung (wie der Zeitrahmen der P1Komponente) auftreten können. Es jedoch nicht klar, ob Aktion Wahrnehmung Interferenz (Impairment) Effekte Zusammenhang Verarbeitung verfügen bei späteren Verarbeitung (wie der Zeitrahmen der N1Komponente).auftreten kann

Die letzte Studie (Kapitel 5) bewegt sich aus dem Labor auf ein angelegtes Einstellung wo es wurde gezeigt dass ein Roboter "CuDDler" (A * Star)Namen kann als Werkzeug verwendet werden die gemeinsame Aufmerksamkeit Fähigkeiten (sowohl Einleitung und Reaktion auf gemeinsame Aufmerksamkeit) von Kindern mit Autismus Spektrum Störung zu verbessern

Zusammengefasst deuten diese Kapiteldass sowohl vorsätzliche Gewichtung und Feature Bindung könnte während die Planung Maßnahmen und dass Aktion Wahrnehmung Kongruenz oder Interferenzeffekte sind abhängig von welcher Ebene der Wahrnehmungsverarbeitung erforderlich(auf der Ebene der Dimensionen oder Merkmale) auftreten. Es wird vorgeschlagen dass Verarbeitungen auf der Ebene der Dimensionen durch den absichtlichen Gewichtungsmechanismus erfolgen, die Effekte zu Kongruenz führt. Während Verarbeitung auf der Ebene der Funktionen Funktion Bindung könnte aktivieren die zu Interferenzeffekten führt. Schließlich ist zu sehen wie Wissen im Labor über kognitive Psychologie erworben kann in realen Welt Einstellungen angewendet werden; hier die Verbesserung der gemeinsamen Aufmerksamkeit Fähigkeiten von Kindern mit ASD).

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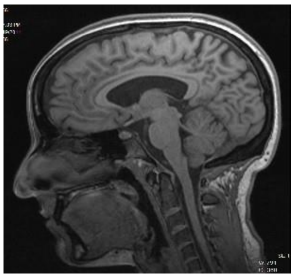

Kelsey Carlson
E-mail: kelsey.leigh.carlson@gmail.com
Phone: +49-176-323-11647
Nationality: American

EDUCATION

- Ludwig Maximilians Universität München, **PhD candidate** in the General and Experimental Psychology Department, October, 2013 - **current**
- Agency for Science, Technology and Research (A*STAR), Singapore, June 2015 – June 2016
- Ludwig Maximilians Universität München, M.Sc. in Neuro-Cognitive Psychology, 2012
  GPA: 1.59 (1.0 = highest grade – 5.0 = lowest grade)
- University of Iowa, B.S. in Psychology, 2009
  GPA: 3.49 (4.00 = highest grade – 0 = lowest grade)
- Iowa Central Community College, A.A. in Biology, 2006
  GPA: 3.80 (4.00 = highest grade – 0 = lowest grade)

MASTER'S THESIS

- The role of the pre-SMA during action selection: A TMS study
  Grade: 1.3 (1.0 = highest grade – 5.0 = lowest grade)

SKILLS

- **Experimental Methods:** Transcranial Magnetic Stimulation (TMS), Functional Magnetic Resonance Imaging (fMRI), Electroencephalogram (EEG), application & scoring of psychological questionnaires
- **Programs:**
  Advanced Knowledge: E-Prime, SPSS, Brainsight, Word, Power Point, Excel
  Basic knowledge: MatLab, Statistical Parametric Mapping (SPM 8), FSL, WorldViz 3.0
- **Overall:** ability to search for & determined relevant literature, recruit subjects, invent paradigms & implement them, analyze & interpret statistics, present findings in manuscripts & presentations.

RSEARCH EXPERIENCE (7+ years)

• **15.06.15 – 14.06.16**
Agency for Science, Technology and Research (A*STAR), Singapore
Researcher, Department of Autonomous Vehicle

- Tested the ability of robot CuDDler (A*STAR) to improve joint attention skills of children with ASD.
- Collaborated with Dr. Yeow Kee Tan, Alvin Hong Yee Wong (M.S.), engineering, and design teams to design new HuGGler robot.
- Collaborated with Pin Sym Foong in design and development of tablet-assisted activity program for unfamiliar caregivers of people with dementia.
- Collaborated with Alvin Hong Yee Wong (M.S.) to arrange project to test HuGGler robot's ability to decrease depression and loneliness in Nursing Home residents.

• **01.10.13 – 31.05.15**
Ludwig-Maximilians-Universität (Munich, Germany)
Researcher, Department of General & Experimental Psychology

- Collaborate with Prof. Dr. Agnieszka Wykowska using behavioral measures & EEG to investigate action planning/control and perception.

• **01.06.2012 – 30.09.13**
Ludwig-Maximilians-Universität (Munich, Germany)
Research Assistant, Department of Experimental Psychology

- Collaborate with Dr. Paul Taylor using TMS to investigate the role of the pre-SMA in task switching & choice.
- Collaborated with Dr. Dragan Rangelov to investigate the role of Phosphenes induced by TMS in cuing attention.
- Collaborated with Francesca Bocca (PhD candidate) to investigate the role of the rANG in attention during compound search task by assisting in application of combined EEG & TMS methodology.
  - Assisted in organizing trip from Munich to collaborating lab in Regensburg for 17 subjects

• **15.07.2011 – 31.03.2012**
Ludwig-Maximilians-Universität: Klinikum Großhadern (Munich, Germany)
Research Assistant, Department of Neurology

- Collaborated with Dr. Virginia Flanagin to investigate gender differences in spatial navigation by assisting in creating a series of virtual mazes in WorldViz 3.0 and testing participants.
- Assisted during fMRI experiments.

• **Summer Semester 2011**
Ludwig-Maximilians-Universität: Klinikum Großhadern (Munich, Germany)
Research Assistant, Department of Neurology

- Collaborated with Dr. Virginia Flanagin to investigate gender differences in spatial memory & navigation using both behavioral & fMRI data.
- Final paper: Carlson, K (Research Project 2, Summer 2011). Gender Differences in Spatial Memory & Navigation

• **Winter Semester 2011**
Ludwig-Maximilians-Universität: Klinik für Psychiatrie und Psychotherapie (Munich, Germany)
Research Assistant, Klinische Psychologie und Psychophysiologie

- Collaborated with Prof. Dr. Kristina Hennig-Fast to investigate moderation of aggression induced by ostracism in Borderline personality disorder (BPD) patients.
- Final paper: Carlson, K (Research Project 1, Winter 2011). Moderation of Aggression Induced by Ostracism in BPD Patients

• **August 2008 - July 2009**
University of Iowa: Hospital & Clinics (Iowa City, IA, USA)
Research Volunteer

- Assisted Daniel T. Tranel (PhD) & Janelle Beadle (RA, PhD) applying a modified Ultimatum Game & standardized psychology measures to investigate the effects of ventromedial prefrontal damage on emotions & decision making.
- Assisted Janelle Beadle (RA, PhD) in preparing manuscript: "Measurement of Empathy in a Community Sample of Younger & Older Adults".

• **August 2007- August 2008**
University of Iowa: Hospital & Clinics (Iowa City, IA, USA)
Research Volunteer

- Assisted Erik K. St. Louis (MD) & Joel Dennhardt (RA, BS) in collection of EEG data with a focus on epileptic patients.
- Collaboration with Steven J. Luck to investigate brain activity in coma patients using EEG.

TEACHING EXPERIENCE

- Training Computer Science Master's student in experimental methods for Interdisciplinary Project.
- Trained two student Research Assistants in EEG lab.
- Taught TMS practical course to 20 students: introduced method of TMS, monitored students on application of method, addressed questions.
- Trained three students on method of TMS: taught method of TMS, monitored students on application of method, supplied relevant literature, consulted on paradigms, assisted in subject recruitment, addressed questions.

PRESENTATIONS

- Carlson, K., Wong, A.H.Y., Dung1,T.A., Wong, A.C.Y., Tan, Y.K., Wykowska, A. (2015, November). Enhancing Joint Attention Skills in Autistic Children via a Robot. Poster presented at the seventh meeting of The International Conference on Social Robotics, Paris, France.
- Carlson, K. Moderation of Aggression Induced by Ostracism in BPD Patients. June 24 – 26, 2011. Munich Multisensory Perception Symposium at Holzhausen am Ammersee (Munich, Germany).

ADMINISTRATIVE EXPERIENCE

- maintaining lab & equipment, maintaining & organizing documents, monitoring spending of funds allocated to subject recruitment, assisting in deciding which equipment to invest in, performing tours of TMS lab to outside scientists