Cortex

**Research report**

# Grasp preparation modulates early visual processing of size and detection of local/global stimulus features

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## ABSTRACT

Preparing to grasp objects facilitates visual processing of object location, orientation and size, compared to preparing actions such as pointing. This influence of action on perception reflects mechanisms of selection in visual perception tuned to current action goals, such that action relevant sensory information is prioritized relative to less relevant information. In three experiments, rather than varying movement type (grasp *vs* point), the magnitude of a prepared movement (power *vs* precision grasps) was manipulated while visual processing of object size, as well as local/global target detection was measured. Early event-related potentials (ERP) elicited by task-irrelevant visual probes were enhanced for larger probes during power grasp preparation and smaller probes during precision grasp preparation. Local targets were detected faster following precision, relative to power grasp cues. The results demonstrate a direct influence of grasp preparation on sensory processing of size and suggest that the hierarchical dimension of objects may be a relevant perceptual feature for grasp programming. To our knowledge, this is the first evidence that preparing different magnitudes of the same basic action has systematic effects on visual processing.

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## 1. Introduction

It is well known that the visual properties of objects can influence subsequent motor processing, for example features such as spatial location, orientation and size of objects can automatically prime corresponding motor parameters (Craighero, Fadiga, Umilta, & Rizzolatti, 1996; Hommel & Prinz, 1997; Tucker & Ellis, 1998). These findings are interpreted as evidence for a tight coupling of action and perception and

current theories suggest that this coupling is bi-directional (Hommel, Müsseler, Aschersleben, & Prinz, 2001). The theory of event coding proposes a shared representation for perception and action, resulting in bidirectional effects between the two domains such that observing events activates associated motor actions, and performing actions also activates associated perceptual events (Prinz, 1984).

The ways in which perception can influence action have been widely investigated (for a review see Vogt &

Thomaschke, 2007), however much less is known about how exactly the planning of simple actions can modulate online visual perception. Most of the evidence for effects of action on perception comes from motor-visual priming paradigms, which investigate perceptual processing of stimuli that share relevant features to a planned action, and have revealed that perception can indeed be biased toward action relevant features. Early behavioural experiments (Craighero, Fadiga, Rizzolatti, & Umilta, 1999) demonstrated that the processing of a visual stimulus is facilitated if the stimulus has the same orientation as a prepared grasping action. Subsequent evidence for motor-visual priming has compared grasping and pointing movements and demonstrated that the processing of object size is selectively enhanced during grasp preparation (Fagioli, Hommel, & Schubotz, 2007) as well as processing of object orientation (Bekkering & Neggers, 2002; Gutteling, Kenemans, & Neggers, 2011; Hannus, Cornelissen, Lindemann, & Bekkering, 2005). These findings suggest that action preparation may tune incoming sensory information to the perceptual features relevant for the upcoming action, resulting in a bias in visual processing to match the prepared action.

Whereas there are now numerous behavioural studies showing effects of action preparation on vision, the neural correlates of motor-visual priming remain largely uninvestigated. One exception using electrophysiology (Wykowska & Schubö, 2012) combined a movement task (grasping vs pointing) and a visual search for size and luminance targets and found facilitated performance on action-perception 'congruent' conditions (i.e., grasping facilitated size targets and pointing facilitated luminance targets). This pattern was reflected by a modulation of early event-related potential (ERP) components, providing supporting evidence that action affects early perceptual processing. That study found that qualitatively different actions (i.e., grasping vs pointing) can prime different aspects of visual processing, demonstrating a large-scale effect of action preparation on visual processing. However, it remains unclear whether preparing different versions of the same basic action can also lead to subsequent differences in visual processing. If action preparation indeed tunes incoming sensory information toward features relevant to the prepared action, then specific perceptual features (e.g., large vs small objects) should be modulated, as well as the broader feature dimensions (e.g., size vs luminance targets) previously investigated (Wykowska & Schubö, 2012). The key aims of the current study were i) to further investigate to extent to which action preparation can influence visual processing, specifically whether varying preparation of the same grasping action in terms of grasp magnitude and force (i.e., a precision vs a power grasp) would selectively enhance the processing for local vs global aspects of a compound visual stimulus (Navon, 1977), respectively, and ii) to measure visual evoked potentials associated with a small or large probe object in a context of a prepared small (precision) or large (power) grasping action.

A number of findings suggest that the hierarchical structure of stimuli may be influenced by grasp preparation. For example Vainio, Ellis, Tucker, and Symes (2006) found an object affordance size effect (size of task irrelevant objects modulates power/precision grasp responses), however the

effect only occurred when holding a precision device in the right hand and the power device in the left hand. In a further study (Vainio, Ellis, Tucker, & Symes, 2007), right hand responses to the 'local' component of an object (e.g., the stalk of a fruit) were facilitated when it was part of a precision-graspable 'global' object (e.g., a strawberry) while left hand responses to the same object were facilitated when it was part of a power-graspable object (e.g., an apple). These findings suggest that object information pertaining to power and precision grasping is predominantly processed in the right and left hemispheres, respectively, and that the processing of hierarchical structure of objects is linked to power/precision grasping actions. More recently Gable, Poole, and Cook (2013) also used unilateral hand contractions to activate the right or left central parietal hemispheres and observed behavioural facilitation of global and local processing, respectively. Local/global processing is also modulated when stimuli are presented near the hands (Davoli, Brockmole, Du, & Abrams, 2012; Langerak, La Mantia, & Brown, 2013; Thomas, 2015), effects often interpreted as a facilitation of perceptual information relevant to covert manual action preparation (Gozli, West, & Pratt, 2012; Makin, Holmes, Brozzoli, & Farnè, 2012; Reed, Betz, Garza, & Roberts, 2010). Additionally, evidence from a variety of approaches suggests that both precision/power grasping and local/global processing may share a similar pattern of hemispheric lateralization. Findings have long supported the notion that the local and global levels of hierarchical stimuli are predominantly processed in the left and right hemispheres, respectively. Behavioural (Hübner, 1998; Van Kleeck, 1989) as well as imaging studies using Positron Emission Tomography (PET) (Fink, Marshall, Halligan, & Dolan, 1998), functional Magnetic Resonance Imaging (fMRI) (Fink et al., 1996, 1997) and electrophysiology (Evans, Shedden, Hevenor, & Hahn, 2000; Malinowski, Hübner, Keil, & Gruber, 2002) support the lateralization of global (right hemisphere) and local (left hemisphere) processing. Some causal evidence is provided from neuropsychological studies of patients with left/right temporal-parietal lesions exhibiting selective impairment in local/global stimulus processing (Robertson & Lamb, 1991; Robertson, Lamb, & Knight, 1988). Although, some inconsistencies exist within the neuropsychological literature, as a common feature of Bálint's syndrome is simultanagnosia, a selective impairment in global stimulus processing with intact local processing, which results from bilateral damage to parieto-occipital junction (Farah, 1990), However in healthy subjects, causal evidence for an asymmetry was provided by Romei, Thut, Mok, Schyns, and Driver (2012) who impaired global processing with right-parietal repetitive Transcranial Magnetic Stimulation (rTMS) and local processing with left-parietal rTMS.

In the current study, motor-visual priming of local/global stimulus features was investigated in three experiments. In Experiment 1, participants were required to detect a target stimulus presented at the local or global level of a compound stimulus following a cue to prepare either a power or precision grasp. If the magnitude of grasp preparation biases visual processing toward stimulus features relevant for the upcoming action, then detection of local targets should be facilitated during the preparation of precision grasping relative to power grasping, and detection of global targets should be

facilitated during power grasping, relative to precision grasping. Experiment 2 sought to replicate findings from Experiment 1 while also reducing the number of local elements within the compound stimuli, a manipulation known to reduce the commonly observed global bias in tasks using hierarchical stimuli (Kimchi, 1988; Martin, 1979; Yovel, Yovel, & Levy, 2001). This was done in order to investigate whether effects of action preparation on local/global processing are dependent on the commonly observed global bias in visual processing.

Experiment 3 utilized the fine temporal resolution of electroencephalography (EEG) to investigate the effects of grasp preparation on processing of visual size, aiming to directly demonstrate a selective effect of grasp preparation on early stages of processing in visual cortices. This experiment also enabled a further investigation of the behavioural effects of global/local processing during grasp preparation using this adapted experimental design. Similarly to Experiments 1 and 2, participants were cued to prepare a power or precision grasp before being presented with a compound stimulus. Also as in Experiments 1 and 2, they were instructed to detect a target shape that could appear at either the local or the global level of the compound stimulus, or it could be absent from the display. On two thirds of trials, during the cue-target interval, a task-irrelevant visual probe was presented that could either be relatively small or large. In visual processing, enhanced ERP components have been observed in response to a task-irrelevant visual probe stimulus presented in an attended area relative to an unattended area of space (Hillyard & Anllo-Vento, 1998; Hillyard, Vogel, & Luck, 1998). Similar effects have been observed at the goal location of eye movements (Eimer, Van Velzen, Gherri, & Press, 2006; Eimer, Van Velzen, Gherri, & Press, 2007) and at effector and goal locations of reaching movements during movement preparation (Gherri, Van Velzen, & Eimer, 2009; Job, de Fockert, & van Velzen, 2016; Mason, Linnell, Davis, & Van Velzen, 2015) reflecting adaptive modulation of sensory processing tailored to the specific movement being prepared. Recent data suggest that the early P1/N1 components can also reflect a biasing mechanism operating on processing of other stimulus features, not just spatial locations (see Zhang & Luck, 2009). If the behavioural effects of grasp preparation reflect a similar adaptive sensory modulation we would expect that early ERPs elicited by the visual probes should be modulated in line with the probes' compatibility with the prepared grasp. This would mean that early components (P1 and N1) elicited by the large probe should be enhanced in amplitude during the preparation of a power grasp relative to a precision grasp, while the components elicited by the small probe should be enhanced during precision relative to power grasps.

## 2.     Experiment 1

### 2.1.     Participants

A total of 16 participants (13 female) with a mean age of 21 years (SD = 4.02) participated in return for course credits or £10. All participants were right handed (mean laterality quotient (Veale, 2014) = 92.21, SD = 11.06) and reported normal or corrected to normal vision. Participants provided written informed consent in accordance with the ethical guidelines presented in the 1964 declaration of Helsinki.

### 2.2.     Stimuli and task

A local/global target detection task run with E-prime software (Schneider, Eschman, & Zuccolotto, 2002) required participants to respond when presented with a target shape stimulus. The target shape could appear at either the local or the global dimension of a compound stimulus (target present trials) or the stimulus could be comprised only of non-target shapes (target absent trials). Compound stimuli were composed of 13—20 local shapes (squares, circles or crosses) (.76° visual angle) arranged into a global configuration (square, circle or cross) (3.8° visual angle). All shape combinations at the local and global dimensions were presented, excluding same-shape combinations.

On each trial, before target presentation, a coloured fixation cross (.91° visual angle) instructed participants to prepare either a power or a precision grasp (see Figs. 1 and 2 for schematics of the response devices and trial procedure, respectively). At 1000 msec following the grasp cue a compound stimulus was presented for 250 msec. Participants were instructed to execute the prepared grasp as fast as possible if a pre-specified target shape (square) was present at either the local or the global dimension and to withhold the grasp in the absence of the target shape. A black fixation cross was presented during the inter-trial interval (ITI) for either 800 msec, 900 msec or 1000 msec, randomly.

### 2.3.     Procedure

Following provision of written consent and the revised Edinburgh Handedness Inventory (Veale, 2014), participants
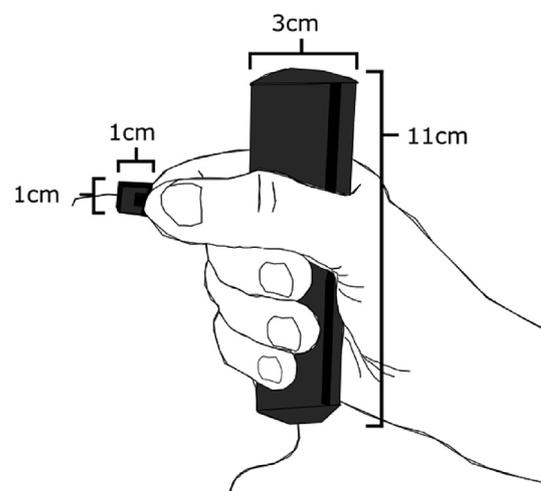


Fig. 1 — Schematic illustration of the power and precision response devices. Precision grasps required pressing the small button with the thumb and the opposing index finger, while power grasps required pressing the large cylindrical device with the whole palmar surface of the hand.
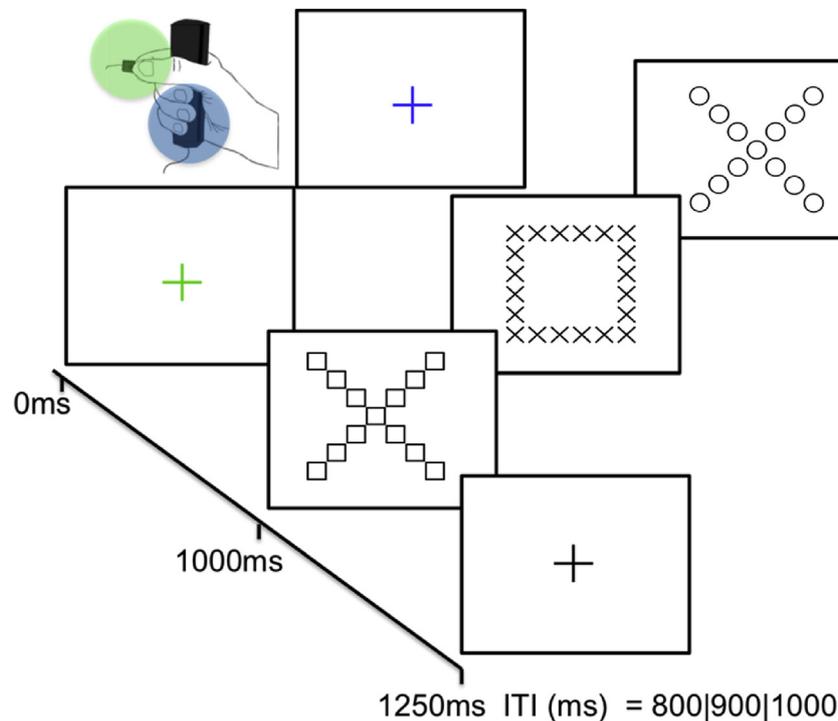
**Fig. 2 – Schematic illustration of the trial procedure with alternate possibilities superimposed above. Following the coloured precision or power grasp cue (0 msec) a compound stimulus was presented for 250 msec that could contain a target shape (e.g., square) at the local or global level, in which case participants executed the cued grasp. If the target was absent, the prepared grasp had to be withheld. The ITI was randomly varied to be 800 msec, 900 msec or 1000 msec. Images are not to scale.**

completed a practice block of 20 randomised trials, followed by six blocks of 60 randomised trials with self-timed breaks between blocks. The entire session lasted approximately 25 min. The mapping between the colour of the cue (blue/green) and the grasp (power/precision) was counterbalanced across participants. The hand used to execute the grasps was also counterbalanced such that half of participants used their right hand for even numbered blocks and their left hand for odd numbered blocks while the reverse was true for the remaining half of participants.

### 2.4. Results

Reaction times (RTs) in response to local and global targets were compared using a 2 × 2 × 2 repeated measures Analysis of Variance (ANOVA) with factors of target level (local/global), grasp (power/precision) and hand (left/right). Table 1 shows the mean percentage errors made across conditions. As errors were made on an average of only 3.5% of trials, they were not

further analysed and only trials in which a correct response was recorded were included in the reaction time analysis.

Fig. 3 shows the mean RTs to global and local targets using power and precision grasps with the left (a) and right (b) hand. A main effect of grasp magnitude was observed with faster execution of precision grasps (M = 421, SD = 79.06) than power grasps (M = 439, SD = 88.94) by 18 msec (SE = 6.73), $F(1, 15) = 7.32$, $p = .016$, $\eta p^2 = .328$. A main effect of target level was also observed with faster responses for global (M = 418, SD = 85.59), compared to local targets (M = 442, SD = 82.42) by 24 msec (SE = 5.18), $F(1, 15) = 22.74$, $p < .001$, $\eta p^2 = .603$. There was no main effect of the hand used, $F(1, 15) = .58$, $p = 456$, $\eta p^2 = .048$ or interactions involving the factor of hand.

An interaction between grasp magnitude and target level was observed ($F(1, 15) = 6.40$, $p = .023$, $\eta p^2 = .299$) indicating that the cued grasp magnitude influenced RTs to local and global targets. Post-hoc t-tests confirmed that responses to local targets were faster using precision grasps (M = 427, SD = 72.68) compared to power grasps (M = 456, SD = 87.32) by 29 msec [standard error of the mean (SEM) = 7.99], $t(15) = 3.63$, $p = .002$. The effect of grasp was not significant for global targets ($t(15) = .93$, $p = .365$).

### 2.5. Discussion

The results of Experiment 1 show that the preparation of either a precision or power grasp can selectively modulate the processing local visual information. Local level targets were detected faster following preparation of a precision grasp,

**Table 1 – Mean percentage error and SD across conditions.**

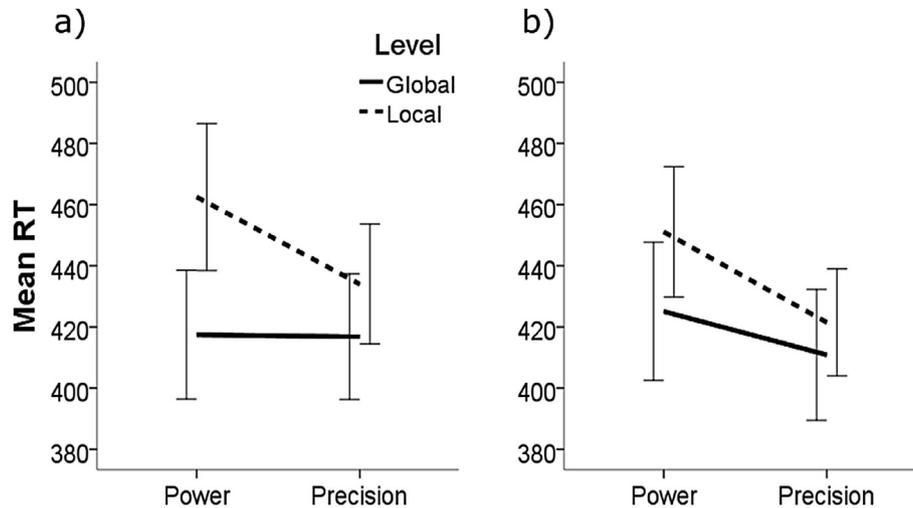| | Global target | | Local target | |
|---|---|---|---|---|
| | Power | Precision | Power | Precision |
| Experiment 1 | 3.04 (2.59) | 3.56 (3.69) | 4.08 (3.91) | 3.21 (3.85) |
| Experiment 2 | 3.56 (3.13) | 4.86 (3.48) | 3.82 (4.52) | 2.69 (2.51) |
| Experiment 3 | 3.20 (2.14) | 3.67 (2.56) | 3.13 (3.35) | 3.05 (2.33) |

Fig. 3 – Mean reaction times (RTs) in milliseconds to target stimuli presented at the global and local levels of a compound stimulus, separated for power and precision grasping. Responses are made with either the left hand (a) or the right hand (b). Error bars represent ±1 SE.

relative to a power grasp. This finding suggests that variation in the same basic action (a grasp) can selectively influence detection of a subsequent visual local target. In contrast to previous evidence suggesting a hemispheric asymmetry for power and precision grasping (Vainio et al., 2006, 2007) the hand used to execute the movements had no influence on power/precision response times in Experiment 1.

The effect of the prepared grasp was only present in terms of detection of local targets, whereas global target detection was unaffected by grasp preparation. A possible factor contributing to this asymmetry is that we used compound stimuli that consisted of a relatively large number of densely organized local elements. Previous work has shown that the magnitude of global bias is dependent on stimulus features such as size and density (Kimchi, 1988; Martin, 1979; Yovel et al., 2001). For example displays with densely arranged local elements spaced close together promote a strong global precedence (Caparos, Linnell, Bremner, de Fockert, & Davidoff, 2013; Enns & Kingstone, 1995; Martin, 1979), meaning that global target detection is greatly facilitated relative to local target detection. In the current study, responses were indeed substantially faster to global, compared to local, targets, which may have obscured any subtle effects of grasp preparation on detection of global targets. Experiment 2 was therefore run in order to replicate the findings of Experiment 1 and to investigate the effects of action preparation on detection of local and global targets in displays in which the global level of the compound stimulus was made less salient by using fewer and less densely organized local elements.

## 3. Experiment 2

### 3.1. Participants

A total of 16 adults (12 female) with a mean age of 24 years (SD = 4.83) participated in return for £10. All participants were right handed (mean laterality quotient (Veale, 2014) = 87.5,

SD = 23), and reported normal or corrected to normal vision. Participants provided written informed consent in accordance with the ethical guidelines presented in the 1964 declaration of Helsinki.

### 3.2. Stimuli and task

The task was identical to Experiment 1, except the compound stimuli consisted of fewer local shapes (9–12) spaced further apart (see Fig. 4). This manipulation of the saliency of the global level has been previously successfully used in order to reduce the relative saliency of the global level (Caparos et al., 2013).

### 3.3. Results

Errors were made on an average of only 2.9% of trials, so were not further analysed. RTs were analysed using the same 2 (target level: local vs global) × 2 (grasp: power vs precision) × 2 (hand: left vs right) ANOVA as Experiment 1. Fig. 5 shows the mean RTs to global and local targets using power and precision grasps with the left (a) and right (b) hand. A main effect of grasp magnitude was observed with faster precision responses (M = 468, SD = 83.68) compared to power (M = 489, SD = 83.25) by 21 msec (SE = 5.37), $F(1, 15) = 15.82$, $p = .001$, $\eta p^2 = .513$. No main effect of target level ($F(1, 15) = .838$, $p = .374$, $\eta p^2 = .053$) or hand ($F(1, 15) = .008$, $p = .931$, $\eta p^2 = .001$) was found.

A marginally significant interaction between the target level (local/global), the grasp magnitude (power/precision) and the hand used (left/right) was observed, $F(1, 15) = 4.56$, $p = .050$, $\eta p^2 = .233$. To investigate this interaction further, separate two-way ANOVAs with factors of level (local/global) and grasp magnitude (power/precision) for each hand confirmed a significant interaction between level and grasp, $F(1, 15) = 7.97$, $p = .013$, $\eta p^2 = .347$ for right hand responses. Post-hoc t-tests revealed that right hand responses to local targets were faster using precision (M = 460, SD = 68.61)
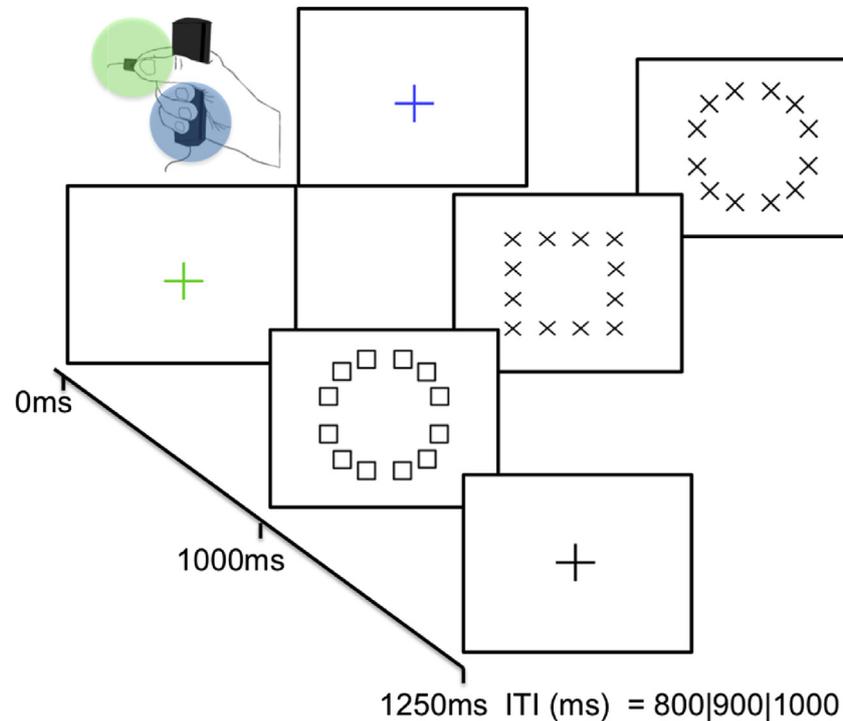
Fig. 4 — Schematic illustration of the trial procedure with alternate possibilities superimposed above. Following the coloured precision or power grasp cue (0 msec) a compound stimulus was presented for 250 msec that could contain a target shape (square) at the local or global level, in which case participants executed the cued grasp. If the target was absent, the prepared grasp had to be withheld. The ITI was randomly varied to be 800 msec, 900 msec or 1000 msec. Images are not to scale.
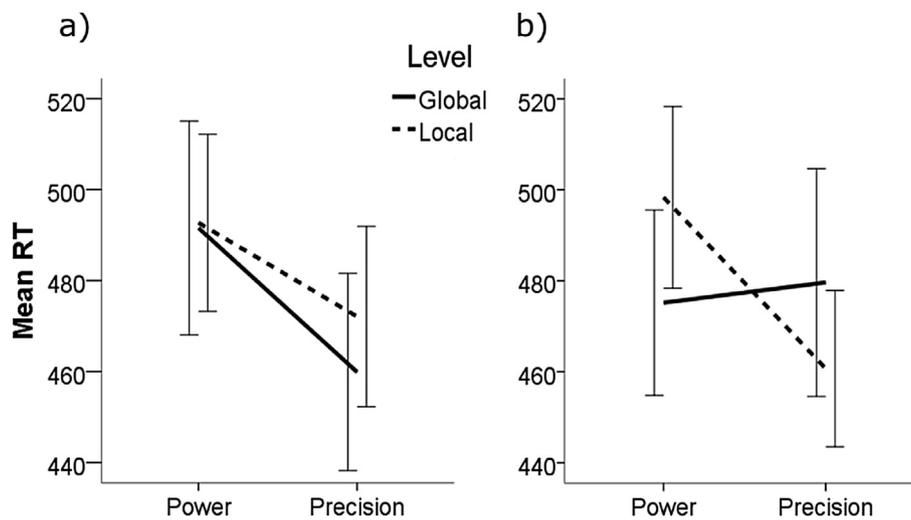


Fig. 5 — Mean reaction times (RTs) in milliseconds to target stimuli presented at the global and local levels of a compound stimulus, separated for power and precision grasping. Responses are made with either the left hand (a) or the right hand (b). Error bars represent ±1 SE.

[1] The possibility that detection of this effect was precluded by low statistical power, as a result of an inadequate sample size, is unlikely as given the sample effect size of Experiment 1 and a critical threshold of .05 (two-tailed), a minimum of 12 participants was required for Experiment 2 with .80 statistical power to reject the null hypothesis.

relative to power (M = 498, SD = 79.85) grasps by 38 msec (SEM = 9.21), $t(15) = 4.09$, $p = .001$. This difference was not significant for left hand responses to global targets,[1] $t(15) = -.42$, $p = .684$. The two-way interaction between target level and grasp magnitude was not significant for left hand responses, $F(1, 15) = .409$, $p = .532$, $\eta p^2 = .027$.

### 3.4.    Discussion

The results from Experiment 2 replicated the core finding of Experiment 1 that local level targets are detected faster following preparation of a precision grasp, relative to a power grasp. This time the effect of grasp preparation was present in the absence of a main effect of target level. The influence that grasp preparation has on the processing of local/global information is therefore not dependent on the commonly observed global bias in visual processing.

Unexpectedly, the effect of grasp magnitude on local/global processing in Experiment 2 was only observed in the dominant right hand, compared to Experiment 1 where the effect was not influenced by the hand used to execute the movement. It is unclear why reducing the number of local elements, and in turn the global bias, would limit the effect of grasp preparation on local processing to the right hand. Perhaps the relative increase in the saliency of the local level, predominantly processed by left hemisphere structures (Hübner, 1998; Van Kleeck, 1989), resulted in the right hand specificity of the effect. In addition to this, regardless of the hand used to execute the grasps, precision responses were faster than power responses across both Experiments 1 and 2. This is not in line with the notion that, relative to the right hand, the left hand may be specialized for power grasping (Guiard, 1987).

Experiment 3 was run to obtain a direct measure of the selective effects of grasp preparation on early stages of visual processing in the brain and to replicate the action preparation effect observed in Experiments 1 and 2 using a version of the local/global paradigm adapted for this purpose: We used a similar design to Experiments 1 and 2, combining an action preparation task with a Navon task (1977) requiring detection of a visual target at either the local or global level of a compound stimulus. Additionally, on each trial a task-irrelevant visual probe was presented following action preparation. The probe could be either small or large in size, and the key prediction was that early probe-evoked visual ERPs would be enhanced for small cues following preparation of a precision (vs power) grasp, and enhanced for large probes following preparation of a power (vs precision) grasp.

## 4.    Experiment 3

### 4.1.    Participants

A total of 16 adults (13 female) with a mean age of 25 years (SD = 3.85) participated in return for £10. All participants were right handed (mean laterality quotient = 87.06, SD = 17.00) and reported normal or corrected to normal vision. Participants provided written informed consent in accordance with the ethical guidelines presented in the 1964 declaration of Helsinki.

### 4.2.    Stimuli and task

Stimuli and task were identical to Experiment 2, except for the following aspects: At 1000 msec following the cue prompting participants to prepare either a precision or a power response, a task-irrelevant visual probe stimulus was presented that could be either large (4.8° visual angle), small (1.6° visual angle) or absent with equal probability. Probes were presented for 100 msec, and 600 msec after probe onset, the compound stimulus was presented for 250 msec. Following an error (incorrect grasp) or a time-out (no response within 1200 msec) a feedback tone was delivered via two speakers symmetrically aligned in front of participants. The contrast of the presentation was also reversed in Experiment 3 with white stimuli presented on a black background. Stimuli were presented using the Psychophysics Toolbox extensions (Brainard, 1997) version 3.0.12 implemented in MATLAB (R2014b, version: 8.4). Fig. 6.

### 4.3.    Procedure

Following provision of written consent and the (revised) Edinburgh Handedness Inventory (Veale, 2014), participants completed a practice block of 30 randomised trials, followed by eight blocks of 100 randomised trials with self-timed breaks between blocks. The experimental task lasted approximately 45 min. The mapping between the colour of the cue (blue/green) and the grasp (power/precision) was counterbalanced across participants. Given that effects of interest were limited to the right hand in Experiment 2, only right hand responses were recorded in Experiment 3.

### 4.4.    EEG recording, processing and analysis

EEG was recorded using a BioSemi ActiveTwo amplifier from 64 Ag–AgCl electrodes placed according to the extended 10–20 system at a digitisation rate of 2048 Hz and down sampled offline to 1024 Hz. Electrodes were referenced to the average of electrodes placed on the left and right earlobes. Activity from horizontal eye movements was recorded from a pair of electrodes placed on the outer canthi of the eyes. Vertical eye movement activity was recorded from electrodes placed above and below the left eye. Offline pre-processing of EEG data was conducted using EEGLAB toolbox version 13.4.4b (Delorme & Makeig, 2004). Analysis was conducted using a combination of FieldTrip toolbox (Oostenveld, Fries, Maris, & Schoffelen, 2011) and custom MATLAB scripts.

For analysis of the probe-evoked potentials, continuous EEG data were divided into 700 msec epochs locked to the onset of the probe including a 100 msec pre-stimulus baseline. Epochs including voltages exceeding + and/or −100 μV were automatically rejected prior to analysis. Eye-blink artefacts were corrected for using Independent Component Analysis (ICA). The mean amplitudes of ERP components within pre-defined time windows were extracted for analysis. The mean positive amplitude between 70 and 110 msec post probe onset was extracted as the P1 mean amplitude. The mean of negative amplitudes between 80 and 120 msec post probe onset was extracted as the N1 mean amplitude. Peak measures were extracted from electrode sites PO7 and PO8, which elicited the largest ERPs as observed in scalp maps of averages over all conditions. The difference between the mean P1 and N1 values was computed to obtain a mean peak-to-peak amplitude measure of the N1 component.

For the ERP analysis, the mean peak-to-peak amplitudes of the N1 component evoked by probe stimuli were analysed in a
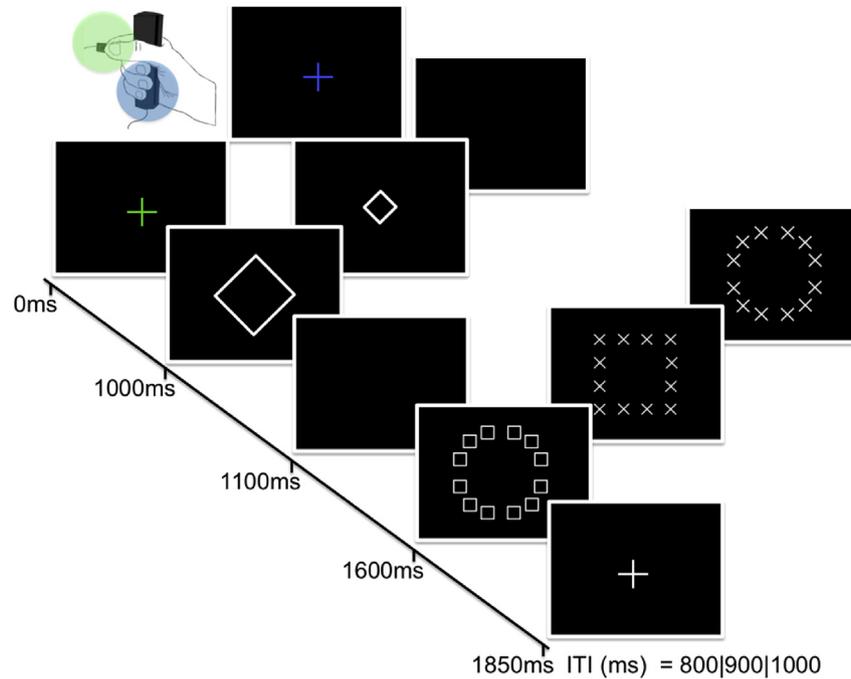
**Fig. 6** – Schematic illustration of the trial procedure with alternate possibilities superimposed above. Following the coloured precision or power grasp cue at the start of each trial, a large, small or absent probe was presented for 100 msec. At 600 msec after probe onset, a compound stimulus was presented for 250 msec that could contain a target shape (e.g., square) at the local or global level, in which case participants executed the cued grasp. If the target was absent, the prepared grasp had to be withheld. The ITI was randomly varied to be 800 msec, 900 msec or 1000 msec. Images are not to scale.

$2 \times 2 \times 2$ repeated measures ANOVA with factors of grasp magnitude (power/precision), probe size (large/small) and electrode hemisphere (PO7/PO8).

### 4.5.　Results

#### 4.5.1.　Behavioural
For the behavioural analysis, correct RTs to targets presented at the global and local dimension of the compound stimuli were compared using a $2 \times 2 \times 2$ repeated measures ANOVA

with factors of target level (local/global), grasp (power/precision) and probe (large/small). Fig. 7 shows the mean RTs for local and global targets presented after a large (a) or small (b) probe stimulus as well as after no probe was presented (c). A main effect of grasp magnitude was found with faster precision (M = 440, SD = 74.15) compared to power (M = 473, SD = 68.68) grasp responses by 33 msec (SE = 5.46), $F(1, 15) = 35.55$, $p < .001$, $\eta p^2 = .703$. A main effect of target level was also found with faster responses for global (M = 448, SD = 77.77), compared to local targets (M = 465, SD = 78.26) by
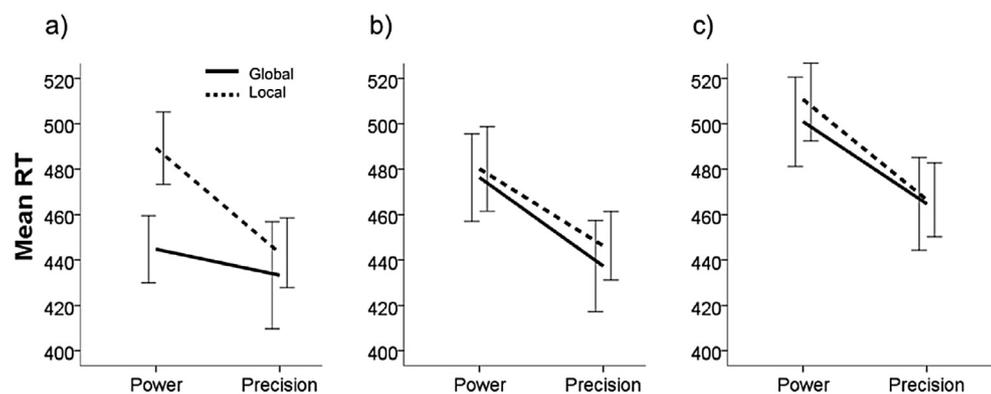


**Fig. 7** – Mean reaction times (RTs) in milliseconds to targets presented at the global (solid line) and local (dotted line) level of compound stimuli, separated for power and precision grasp cues. Compound stimuli are presented following a large (a), small (b), or no probe stimulus (c). Error bars represent ±1 SE.

17 msec (SE = 5.63), $F(1, 15) = 8.85$, $p = .009$, $\eta p^2 = .371$. A significant interaction between target level and size of the probe was observed, $F(1, 15) = 14.56$, $p = .002$, $\eta p^2 = .493$. The interaction between grasp magnitude and target level did not reach statistical significance ($F(1, 15) = 2.09$, $p = .169$, $\eta p^2 = .122$) and neither did the interaction between grasp magnitude and probe size $F(1, 15) = .805$, $p = .384$, $\eta p^2 = .051$. However a significant interaction between target level, grasp magnitude and probe size was found, $F(1, 15) = 13.80$, $p = .002$, $\eta p^2 = .479$. This indicates that the mean RTs to global/local target stimuli were influenced both by the relative size of the task-irrelevant probe preceding the target as well as the prepared grasp. To investigate this interaction further, ANOVAs with factors of grasp magnitude (power/precision) and target level (global/ local) were used for each probe condition (large/small) separately.

Following the presentation of a large probe stimulus (Fig. 7a), the interaction between grasp magnitude and target level was significant ($F(1, 15) = 7.46$, $p = .015$, $\eta p^2 = .332$) and post-hoc t-tests confirmed that responses to local targets were faster using a precision grasp (M = 443, SD = 61.51), compared to a power grasp (M = 489, SD = 63.92) by 46 msec (SEM = 6.15), $t(15) = 7.50$, $p < .001$. This difference was not significant for global targets, $t(15) = 1.01$, $p = .331$. The interaction between grasp magnitude and target level was also not significant following small probes (Fig. 7b), $F(1, 15) = .251$, $p = .624$, $\eta p^2 = .016$. Similarly, an ANOVA with factors of grasp magnitude (power/precision) and target level (global/local) was used for probe absent trials (Fig. 7c) and revealed no significant interaction between grasp magnitude and target level, $F(1, 15) = 2.50$, $p = .135$, $\eta p^2 = .143$.

*4.5.2.  Visual evoked potentials*
Fig. 8 shows the grand averaged event-related potentials (ERPs) elicited by the task-irrelevant probe stimuli. For the N1 mean peak-to-peak amplitude, no main effects of grasp magnitude (power/precision), probe (large/small) or electrode hemisphere (PO7/PO8) were observed ($F(1, 15) = .92$, $p = .352$, $\eta p^2 = .058$, $F(1, 15) = 3.28$, $p = .090$, $\eta p^2 = .108$ and $F(1, 15) = 1.66$, $p = .217$, $\eta p^2 = .100$, respectively). A significant interaction between the size of the probe and the grasp being prepared was observed, $F(1, 15) = 8.95$, $p = .009$, $\eta p^2 = .374$, as well as a significant interaction between the probe size, grasp magnitude and electrode hemisphere ($F(1, 15) = 5.10$, $p = .039$, $\eta p^2 = .254$).

Separate two-way ANOVAs with factors of probe size and grasp magnitude were then run for left and right hemispheres, revealing a significant interaction at left hemisphere sites, $F(1, 15) = 13.54$, $p = .002$, $\eta p^2 = .474$. Post-hoc t-tests confirmed that the mean peak-to-peak size of the N1 component at left electrode sites evoked by large probes was enhanced during the preparation of power grasps (M = 4.22, SD = 4.17), relative to precision grasps (M = 3.15, SD = 4.08), by 1.07 μV (SD = 1.00), $t(15) = 4.25$, $p = .001$. The reverse effect was observed for the N1 at left electrode sites evoked by small probes, with marginally larger mean amplitudes during the preparation of precision grasps (M = 3.13, SD = 3.17), relative to power grasps (M = 2.37, SD = 3.76) by .76 μV (SD = 1.33), $t(15) = -2.30$, $p = .036$ ($p = .072$ following correction for multiple comparisons). At right hemisphere electrode sites the interaction between

probe size and grasp magnitude was non-significant, $F(1, 15) = 2.50$, $p = .135$, $\eta p^2 = .143$.

## 5. General discussion

The results provided here are the first to show an influence of different versions of the same basic action, power and precision grasps, on visual perception of hierarchical information. Experiment 1 demonstrated that the preparation of either small or large grasping actions modulates RTs to local targets presented in compound stimuli. Faster RTs were observed for targets presented at the local level of compound stimuli with a precision grasp, relative to a power grasp. Experiment 2 manipulated the relative saliency of the global level by using fewer local elements in the compound stimuli and observed the same influence of grasp cueing on RTs for local targets, for right hand responses. This shows that the effect of action preparation is not dependent on the commonly observed global bias. Experiment 3 showed that grasp preparation biased early visual ERPs elicited by task-irrelevant probes of varying sizes. The visual N1 component was enhanced for large probes during power, relative to precision, grasp preparation and marginally enhanced for small probes during precision, relative to power, grasp preparation. This demonstrates a direct effect of grasp preparation on early stages of visual processing. Effects of manual reaching and eye movement preparation on sensory processing have been linked to overlapping brain networks involved in action and attention (Astafiev et al., 2003; Corbetta, 1998; Corbetta et al., 1998; Corbetta & Shulman, 2002). Whether similar links exist for grasping movements remains to be determined and future studies should elucidate the brain mechanism activated by a grasp instruction. Furthermore, in Experiment 3, a behavioural effect of probe size on local/global target detection was modulated by grasp, such that large (vs small) probes only facilitated global (vs local) processing during power (vs precision) grasp preparation.

Previous evidence has shown that action preparation can influence visual perception of stimulus features such as orientation (Bekkering & Neggers, 2002; Hannus et al., 2005) and size (Fagioli et al., 2007; Wykowska & Schubö, 2012). These examples show that visual information is biased toward stimulus features relevant for upcoming action, representing the tight coupling of action and perception. Here, the bias is extended to include not only early visual perception of size, but of hierarchical stimulus features. In contrast to the previous evidence that compared the influence of qualitatively different actions (e.g., grasping vs pointing) on visual perception of overall feature dimensions relevant to the actions (e.g., orientation/size and colour/luminance), the findings presented here demonstrate a more fine-grained influence whereby varying the magnitude of the same basic grasping action influences subsequent visual processing. This is likely an important aspect of the adaptive control of movement, such that perceptual features most relevant to the upcoming action are facilitated in visual processing, compared to less relevant features. Additionally, previous demonstrations of action-modulated vision manipulated the prepared action in blocks, rather than randomly cueing actions on each trial,
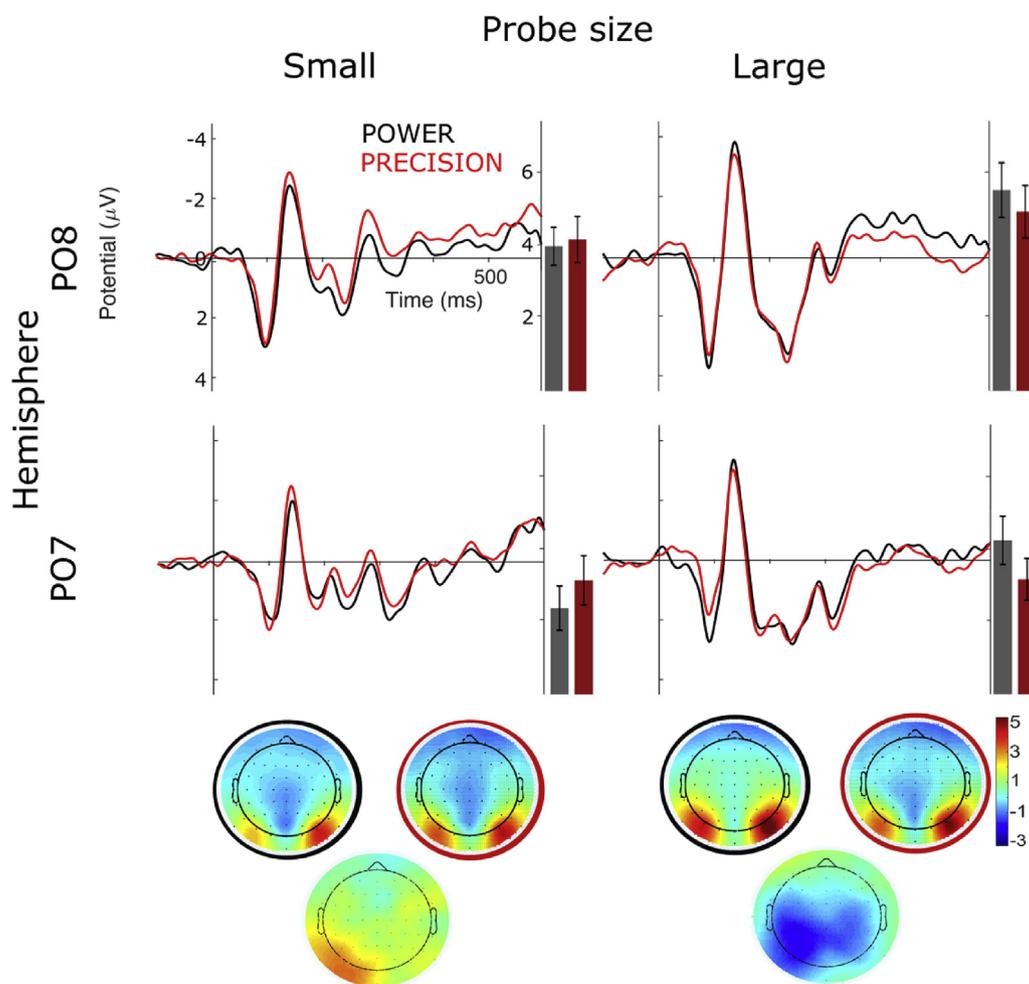
**Fig. 8** – Grand-averaged event-related potentials (ERPs) elicited by the probe stimuli (onset = 0 msec) during power and precision grasp preparation. Bar graphs show the mean peak-to-peak amplitude of the N1 component during power (grey) and precision (red) grasp preparation (error bars represent ±1 SE). Scalp maps show the distribution of the N1 component peak-to-peak amplitude (μV) for each condition (from left to right – small probe power grasp, small probe precision grasp, large probe power grasp, large probe precision grasp) as well as the difference below (power – precision).

with the exception of Wykowska and Schubö (2012), who instead presented the size or luminance targets in separate blocks while varying the cued action trial-by-trial. Our design demonstrated modulated visual information during action preparation where both the cued action (power/precision grasp) and the target stimulus feature (local/global) are manipulated randomly on each trial. This demonstrates a more dynamic adjustment to visual processing as a consequence of action preparation, without the possible confound associated with participant's prior knowledge of the action and/or target stimulus feature before trial onset.

Although grasp preparation altered RTs to the compound stimuli in Experiments 1 and 2, this was not replicated in the probe-absent trials of Experiment 3 as expected. An effect of approximately 35 msec in Experiments 1 and 2 was reduced to just 10 msec in Experiment 3. Only following a large probe stimulus, was an effect of grasping observed on RTs to global/local target stimuli in Experiment 3. A number of differences between the experiments, implemented to enable the use of EEG, may have contributed this loss of effect. For example,

additional trial numbers were required for Experiment 3 and the contrast was also reversed so stimuli were white on a black background. Furthermore, the longer cue-target interval in Experiment 3 (+600 msec), which was used to ensure that trials had the same length as those in which a probe was presented, may have played a role. Modulations of sensory processing in the context of the specific action being prepared have been demonstrated to be temporally dynamic (Mason et al., 2015) and further research is required to determine how grasp preparation affects sensory processing over time. Finally, the mere presence of the visual probes in Experiment 3 may have affected the action-perception effect in general, even on the no-probe trials. Exactly how action-perception interactions are affected by the context in which they are measured is an intriguing question that warrants further work.

Given that RTs to local/global target stimuli in the tasks are gathered from execution of the cued movement itself, it is possible that perception of the local/global target facilitated the action, rather than the inverse. It seems unlikely that the

reaction time effects observed here reflect *visual-motor*, rather than *motor-visual*, priming for a number of reasons. First, participants are always cued to prepare the grasp up to 1600 msec before the onset of the compound stimulus, so visual-motor priming would imply a strategy of inhibiting a movement cue that is highly informative, until after onset of the compound stimulus. More importantly, the pattern of probe-evoked potential effects from Experiment 3 shows a selective influence of the movement cue on visual processing before onset of the compound stimuli. Nevertheless, it is conceivable that visual-motor priming is contributing to some extent to the reaction time effects of grasping on local/global target detection presented here. Separating the cued motor response from the perceptual decision in a dual task design may help to elucidate this further.

## 5.1. Conclusions

It is now widely accepted that perception and action are tightly coupled, such that bidirectional influences exist between the two domains. While the influence of perceptual information on motor processing has been extensively studied, much less is known about how action preparation influences perceptual processing. Actions such as grasping appear to influence the online perceptual processing of features relevant to the upcoming action, which likely reflects a mechanism of selection in visual processing that prioritizes action relevant information in the environment. Previous demonstrations of modulated perception during grasp preparation compared different movement types such as grasping versus pointing. Here, the magnitude of the grasp (power *vs* precision) resulted in specific modulations of early electrophysiological markers of visual perception, as well as faster detection of targets presented at the grasp-relevant dimension of a compound stimulus. Overall, the results suggest overlapping brain mechanisms involved in the motor processes of grasping and perceptual processing of size as well as local/global object perception.

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