

**The effect of healthy aging on the perception–action dissociation.**

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## Abstract

The two visual pathways hypothesis posits distinct brain systems for vision-for-perception and vision-for-action. While this dissociation is well-established in younger adults, its integrity in healthy aging remains unclear. To address this, younger ( $n = 25$ , range: 18–25 years) and older adults ( $n = 25$ , range: 60–95 years) completed estimation and grasping tasks in two experiments. In Experiment 1, two rectangular objects with varying lengths (40 mm and 42 mm) were placed on the “far” and “close” surfaces of a Ponzo illusion board. Despite age-related changes in grasping kinematics, the perception–action dissociation persisted: the illusion influenced estimation, while grasping showed a reversed effect. Experiment 2 tested whether this reversal was due to surface size by removing illusory cues and varying only the background surface size (“big” versus “small”). While estimation was unaffected, surface size modulated grasping in both groups, with a stronger effect in older adults. These findings indicate that the perception–action dissociation is preserved in aging, but older adults rely more on contextual cues during action, potentially reflecting compensatory mechanisms to maintain visuomotor performance in daily life.

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## Introduction

A cornerstone in cognitive neuroscience is the dissociation between visual perception and action; a distinction that profoundly contributed to our understanding of the neural basis of visual behaviours. Mishkin et al. (1983) originally suggested that the ventral visual pathway enables the visual identification of objects, while the dorsal visual pathway facilitates encoding of objects' visual location. Goodale and Milner (1992) later refined Mishkin et al.'s hypothesis in their dual-pathway model, which posits two anatomically and functionally distinct visual pathways. The model proposes that the processes responsible for object identification and recognition ("vision-for-perception" via the ventral pathway) are dissociable from the processes that allow for an individual to shape their hand and grasp an object ("vision-for-action" via the dorsal pathway) (Goodale & Milner, 1992; Milner & Goodale, 2008). This framework states that perceptual judgments about objects can be dissociated from the motor actions directed toward those same objects. Such dissociations are not merely theoretical: they provide an explanation for how the brain maintains specialized systems that serve different behavioural goals.

Empirical support for the dual-stream model first emerged from lesion studies in both non-human primates and neurological patients. Seminal work showed that monkeys with ventral pathway lesions were impaired in object discrimination tasks, whereas those with dorsal lesions struggled with spatial tasks involving reaching (Mishkin et al., 1983; Mishkin & Ungerleider, 1982). This double dissociation was later replicated in humans. Patient D.F., who suffered from visual form agnosia due to ventral pathway damage, was unable to recognize objects or report their size and shape, but still scaled her grip appropriately when reaching to grasp them (Goodale et al., 1991; Milner et al., 1998; Milner & Goodale, 2008; Whitwell et al., 2014). Conversely, individuals with optic ataxia (caused by dorsal lesions) were unable to coordinate their hand movements to interact with objects accurately despite preserved object recognition abilities

(McIntosh et al., 2011; Milner et al., 2003; Pisella et al., 2009). These neuropsychological cases remain crucial in validating the functional dissociation between perception and action.

Beyond lesion studies, a wealth of behavioural evidence has demonstrated the perception–action dissociation in neurotypical adults. Experimental paradigms using visual illusions (such as the Ponzo, Ebbinghaus/Titchener, and Wundt-Jastrow illusions) have been particularly influential. These illusions typically bias perceptual judgments, wherein participants report objects as being different in size or length depending on the context they are presented within. However, when participants are asked to grasp these same objects, their grip aperture often remains appropriately scaled to the actual size, unaffected (or minimally affected) by the illusion (Aglioti et al., 1995; Ganel et al., 2008b; Ozana & Ganel, 2020). This divergence between distorted perception and accurate action has been taken as strong behavioural evidence for the dorsal pathway’s capacity to extract real-world metrics independently of the ventral pathway’s contextual distortions. Importantly, other psychophysical studies show that while manual estimations of object size typically follow Weber’s law—a hallmark of perceptual processing—grasping apertures often violate it, suggesting that action relies on distinct, non-perceptual metrics (e.g., Ganel et al., 2008a). Taken together, these findings reinforce the notion that the two visual systems operate under different principles.

However, evidence for this dissociation is not without controversy. For instance, Rossetti et al. (2017) state that the classical dual-stream model may oversimplify the complexities of visuomotor processing, noting that action and perception can be interdependent, particularly in real-world or pathological contexts. Additionally, some researchers posit that methodological differences between perceptual and action tasks (such as feedback availability, time pressure, and the spatial precision required) may account for the differences in illusion susceptibility, arguing

that contextual illusions cannot count as evidence to support the perception–action dissociation (Franz, 2001; Franz & Gegenfurtner, 2008; Smeets & Brenner, 2006). Contrary to interpretations from studies in support of the dissociation, some researchers argue that actions are not immune to visual illusions, but that illusion effects vary depending on task demands and goals. Despite these critiques, the general consensus remains that, under carefully controlled conditions, perception and action often operate on different representations. This evolving view reinforces the need to examine the dissociation across diverse populations and task conditions to better understand its boundaries and underlying mechanisms.

One research direction has been to explore how the dissociation emerges and changes across the lifespan and in atypical development, where naturally occurring changes in neural organization offer powerful opportunities to test its robustness. As such, recent research has extended this paradigm into developmental and clinical contexts. In typically developing children, the perception–action dissociation appears early. Between the ages of 5 to 8, children’s grasping tends to resist visual illusions like the Ponzo illusion, while perceptual judgments remain biased (Freud et al., 2021). Nevertheless, evidence from Weber’s law paradigms indicates that visuomotor representations are still modulated by perceptual input in early childhood: children obey Weber’s law in various perceptual tasks, but have been found to violate it in action only with non-complex objects, whereas adults show consistent violations regardless of object complexity (Freud et al., 2019; Hadad et al., 2012). This suggests that action and perception are more tightly coupled in childhood, and that the dissociation strengthens with development. However, in atypical development, the dissociation may be attenuated or absent. For example, individuals with amblyopia, autism spectrum disorder, and Williams syndrome often show a reduced dissociation between perception and action, suggesting atypical visuomotor processing

or altered dorsal pathway function (Ahmad et al., 2023; Ahmad et al., 2025; Dilks et al., 2008). These results imply that the perception–action dissociation may be experience-dependent, modulated by age-related constraints and sensitive to alterations in the neural organization.

The apparent susceptibility of the perception–action dissociation to age-related changes poses an important question on the integrity of the dissociation during healthy aging. Aging is accompanied by a notable decline in cognitive, visuomotor, and perceptual abilities (Grady, 2012). This decline is marked by a pronounced deterioration of various visual behaviours, including reduced visual acuity, depth perception, and contrast sensitivity (Song et al., 2023; Swenor et al., 2018). Motor behaviour also becomes less efficient: older adults typically show slower movement execution, larger grip apertures, and reduced grasping precision (Campoi et al., 2023; Maki & McIlroy, 2006; Vasylenko et al., 2018; Voelcker-Rehage & Alberts, 2005). These declines are compounded by changes in brain structure and function, including reduced grey matter volume and altered functional connectivity (Carp et al., 2011; Park et al., 2004; Raz et al., 2005).

These differences may reflect not only physical constraints, but cognitive and neural shifts. For instance, Wermelinger et al. (2018) demonstrated that older adults rely more on external cues, potentially indicating compensatory mechanisms. Aligning with this finding, the compensation-related utilization of neural circuits hypothesis (“CRUNCH”) suggests that older adults recruit additional or alternate brain regions to compensate for age-related declines, even when performance is age-equivalent (Reuter-Lorenz & Cappell, 2008). From a neural standpoint, the dedifferentiation hypothesis suggests that aging blurs the boundaries between specialized systems, leading to a reliance on shared neural resources across different tasks. If the dorsal and ventral pathways become less distinct, one might expect the perception–action dissociation to

degrade. Neuroimaging studies support this possibility: in older adults, the distinctiveness of neural representations is reduced in the motor control network during action tasks (Carp et al., 2011). Notably, older adults also exhibit reduced neural specialization of visual categories in the visual ventral cortex (Park et al., 2004). This suggests that older adults have a diminished ability to efficiently process visual stimuli and produce appropriate motor responses, opening up the possibility that the perception–action dissociation could be weakened with age.

Although grasping behaviour in older adults has been studied, most prior research focuses on kinematic variability, movement slowing, or grip force, and not on the functional dissociation between perception and action. To date, very few studies have directly examined how the perception–action dissociation manifests in older adults. One notable exception is Skervin et al. (2021), who found that older adults’ stair-climbing behaviour was influenced by perceptual distortions, suggesting a breakdown of the dissociation. However, studies using hand-based tasks and visual illusions in this population remain scarce. Whether older adults’ actions remain resistant to illusory bias or whether they become increasingly vulnerable to contextual distortions remains underexplored.

The current study directly examines the perception–action dissociation in aging by testing younger and older adults using the Ponzo illusion. The Ponzo illusion simulates depth by using converging lines to manipulate perceived object size. When an object is placed on the “far” end of the illusion, it appears larger than an identical object on the “close” end. While perception is typically influenced by this illusion, visually guided actions remain veridical. In Experiment 1, participants grasped and estimated the length of objects placed on different positions of a Ponzo illusion board. In Experiment 2, the illusion was removed, and only the surface size context was

manipulated. This design allowed us to isolate the influence of relative-size cues from that of the illusory depth manipulation.

We predicted that younger adults would replicate the classic dissociation: perception would be biased by the illusion, while action would remain veridical. For older adults, two outcomes were possible. If aging preserves the functional segregation of dorsal and ventral pathways, then the dissociation should remain intact. Alternatively, if compensatory visuomotor strategies or neural dedifferentiation alter functional processing, older adults might exhibit susceptibility to the illusion in both the grasping and estimation tasks. In both cases, we predicted that older adults would exhibit alterations in their visuomotor behaviours, even if the perception–action dissociation remained intact. By directly comparing younger and older adults, this study aimed to provide a critical test of whether the perception–action dissociation remains functionally intact in aging, offering new insight into how visuomotor specialization may evolve across the lifespan.

## Experiment 1

### Methods

#### *Participants*

Twenty-five younger adults (14 female;  $M = 19.88$  years,  $SD = 1.81$ , range = 18–25) and twenty-five older adults (23 female;  $M = 76.04$  years,  $SD = 5.30$ , range = 69–95) participated in Experiment 1. All participants self-identified as right-handed, confirmed using a modified version of the Edinburgh (Oldfield, 1971) and Waterloo (Brown et al., 2006) handedness questionnaires (see Stone et al., 2013 for details). Visual acuity was verified using a Snellen chart, and older adults completed the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) to screen for cognitive impairment. Younger adults were recruited from York University's undergraduate research pool, while older adults were recruited from the Elspeth Hayworth Centre for Women.

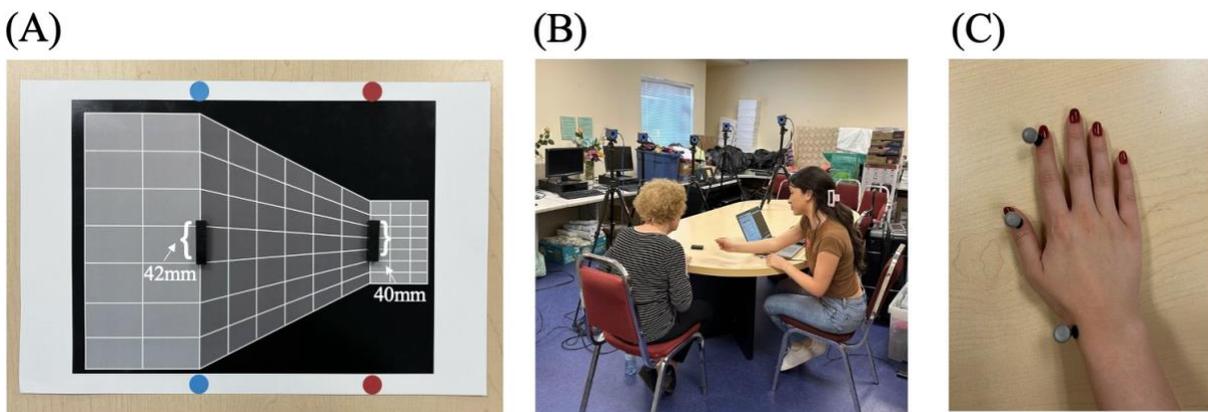
The study was approved by the Research Ethics Board of York University. All participants provided informed, signed consent prior to testing, after receiving an explanation of the study's procedures and potential risks. Participants received either course credit (younger adults) or monetary compensation (older adults). The procedures were based on methodologies used in previous work on grasping and perceptual estimation under visual illusions (e.g., Ahmad et al., 2022; Freud et al., 2021).

#### *Apparatus and Stimuli*

Participants sat in front of a table on which a printed Ponzo illusion board was placed (Figure 1A). The board consisted of a flat surface containing converging diagonal lines that created illusory depth. Objects were positioned at either the “close” or “far” surface of the board. Two black rectangular 3D plastic blocks were used as target objects, matched in height (10 mm),

width (10 mm), and color (black), but differing slightly in length: one measured 40 mm (“shorter”) and the other 42 mm (“longer”).

Kinematic data were recorded using the OptiTrack motion-capture system at a sampling rate of 100 Hz (Figure 1B). Five Prime 13w cameras, either wall-mounted in the lab or placed on portable tripods for off-site collection, captured participants’ grasping and estimation movements at x, y, and z-coordinates. Reflective spherical markers were attached to the participant’s index finger, thumb, and wrist (Figure 1C).



**Figure 1.** (A). *Experimental setup.* The “close” surface is marked with blue stickers and the “far” surface is marked with red stickers. Due to depth cues, objects placed on the far surface are perceived to be longer than they are in actuality. (B). *OptiTrack system set-up.* (C). *Marker placement.*

### ***Procedure***

Participants completed two tasks: a grasping task and a perceptual estimation task, with the order counterbalanced across participants. In the grasping task, participants used their thumb and index finger to grasp the object along its length, lift it, and return it back to the table at the original position before moving their hand back to the home position. In the estimation task, participants were instructed to open their thumb and index finger to indicate the perceived length

of the object, without making contact. They held the indicated aperture for approximately two seconds before returning to the home position.

In each task, each object (shorter and longer) appeared on either the close or far surfaces, for a total of 30 randomized presentations per condition (object size  $\times$  location), resulting in 60 trials per task.

### ***Data Analysis***

Data were processed and analyzed using custom, in-house Python scripts and JASP (JASP Team, 2024). For grasping trials, 3D trajectories of the object, index finger, thumb, and wrist were recorded. Grip aperture was calculated as the Euclidean distance between the thumb and index finger markers. Movement onset was defined as the first frame at which either the index finger or wrist velocity exceeded 20 mm/s for 20 consecutive frames. Movement offset was determined using two algorithms: (1) a velocity-based condition in which the object velocity exceeded 50 mm/s while aperture change remained under 0.5 mm for 10 consecutive frames, and (2) a position-based condition where grasp completion was identified by marker position thresholds in the Y and Z axes combined with low aperture variability. The earliest valid time point across the two criteria was selected. For estimation trials, movement onset was defined using the same velocity threshold as in grasping, while movement offset was marked by the final frame of the recording (“endpoint”). All trials were visually inspected and manual adjustments were made when the algorithm failed to detect clear movement boundaries.

For each grasping trial, grip aperture values were extracted at 10% increments from movement onset to movement offset, allowing for a time-normalized trajectory analysis. The maximum grip aperture (MGA) was identified as the peak aperture between movement onset and

offset. For estimation trials, the aperture value at the final frame was used to index perceived object length, as participants did not physically interact with the object.

To correct for individual variation in finger width (which might induce artificial aperture differences between age groups), MGA values were normalized using a procedure adapted from Ganel et al. (2012). For each participant, the grip aperture at the final frame of each trial was averaged across all trials. Then, a constant value of 40 mm (corresponding to the length of the shorter object) was subtracted from this average to estimate each participant's finger width. Note that subtracting the fixed value of the shorter object rather than the actual object size ensured that effects of size were preserved. This estimated finger width was then subtracted from all MGA values and from the grip aperture values at each time point (0–100%) for every trial. This correction could not be applied to estimation trials, so analyses for that task were conducted on raw values.

Effect of the illusion was calculated by subtracting the average response for close trials from far trials, separately for each object size and task. Positive values reflected the expected influence of the Ponzo illusion, wherein participants opened their fingers wider, on average, for objects placed on the “far” surface. Size sensitivity was calculated as the difference in response between big and small objects. Group comparisons and task effects were assessed using ANOVAs and t-tests conducted on both raw and normalized data.

## **Results**

### ***Perception–Action Dissociation***

To examine whether the Ponzo illusion differentially influenced perception and action, a mixed-design ANOVA with task, group, and perceived distance was conducted on endpoint and adjusted MGA values. This analysis revealed a significant interaction between task and perceived

distance [ $F_{(1, 48)} = 44.99, p < .001, \eta_p^2 = .484$ ], indicating a robust dissociation: estimations were biased in the direction of the illusion (far > close), whereas grasping responses showed a reversed pattern (Figure 2A). No significant three-way interaction emerged [ $F_{(1, 48)} < 1$ ], suggesting that the dissociation was preserved in both age groups. Follow-up ANOVAs conducted separately for each group confirmed significant interactions between task and perceived distance [Younger:  $F_{(1, 24)} = 24.52, p < .001, \eta_p^2 = .505$ ; Older:  $F_{(1, 24)} = 22.18, p < .001, \eta_p^2 = .480$ ], reinforcing the presence of a dissociation between perception and action in both age groups.

Alongside this preserved dissociation, grasping movements showed a small but reliable reversed illusory effect: grip apertures were larger for objects on the *close* surface. This effect was observed in both age groups, with no significant difference between younger and older adults (Younger:  $M = -0.62, SD = 1.44$ ; Older:  $M = -1.28, SD = 0.98$ ). One-sample t-tests confirmed significant deviation from zero [Younger:  $t(24) = -2.13, p = .043$ , Older:  $t(24) = -6.52, p < .001$ ]. An interaction between group and perceived distance approached significance [ $F_{(1, 48)} = 3.64, p = .062, \eta_p^2 = .071$ ], suggesting that the reversed, negative effect was greater in older adults. This motivated Experiment 2, where we further explored this finding.

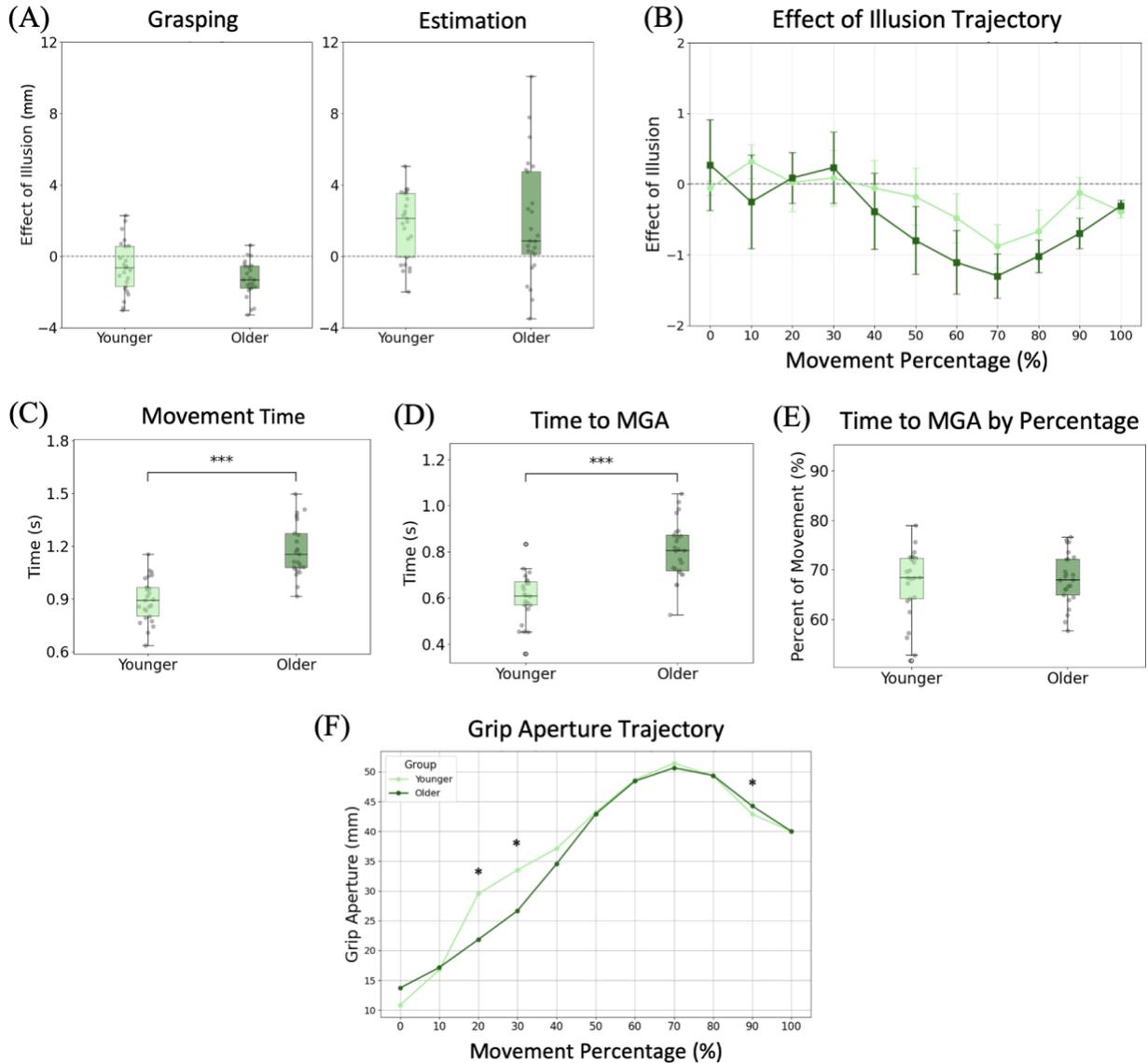
Despite the observed perception-action dissociation observed for both age groups, it remains possible that older adults' grasping behaviours might be modulated by the illusion at other phases of the movement trajectory (i.e., before the MGA). To test this, we computed the illusion effect at each 10% interval (far – close) (Figure 2B). Both age groups showed a negative illusion effect during mid-to-late stages of movement, consistent with the reversed MGA pattern. No significant group differences were found at any timepoint ( $ts < 1.88; ps > .723$ ), suggesting that both groups were similarly affected by the illusion across the movement trajectory.

### *Age-Related Kinematic Variables*

Although the two groups exhibit a similar pattern of perception-action dissociation, older adults exhibited significant kinematic differences, suggesting altered visuomotor execution. We compared the temporal profile of the grasping movements using an independent t-test that revealed that older adults had longer movement time ( $t = 7.32, p < .001, d = 0.407$ ) and took longer to reach the MGA ( $t = 6.26, p < .001, d = 0.378$ ) (Figures 2C and 2D).

Consistent with previous literature, these results suggest that although grasping responses were largely resistant to the illusory context in terms of aperture scaling, the temporal dynamics of movement execution varied with age. Yet, despite these visuomotor differences when looking at absolute timing, the proportional structure of the movement (measured by percent time to MGA) did not differ between groups ( $t = 0.44, p = .662$ ) (Figure 2E). This suggests that although older adults moved more slowly and reached peak grip aperture later in time, the relative timing within the reach was preserved.

To further explore temporal differences, we examined group differences in grip aperture at each 10% interval of the movement trajectory (Figure 2F). FDR-corrected t-tests showed significant differences at 20% ( $t = 3.76, p = .0051$ ), 30% ( $t = 3.34, p = .0089$ ), and 90% ( $t = -2.67, p = .0284$ ), where younger adults displayed larger grip apertures early in the reach and smaller grip apertures later in the reach. This supports the interpretation that age-related motor differences may be most pronounced during movement initiation and movement offset.



**Figure 2.** Results for Experiment 1. (A). Illusory effects for grasping (left) and estimation (right) across groups, derived from finger aperture in millimetres. Boxplots show group-level distributions of the illusion effect (far – close), with individual data points overlaid. (B). Effect of the illusion (far – close) plotted across movement time, calculated at 10% intervals from movement onset to offset. (C). Movement time (in seconds) by group. (D). Time to MGA (in seconds) by group. (E). Time to MGA expressed in terms of percentage of the movement. (F). Grip aperture in millimetres plotted across movement time, calculated at 10% intervals from movement onset to offset. Error bars in all figures represent standard error of the mean (SE).

### Interim Discussion

The results of Experiment 1 confirmed the presence of a perception–action dissociation in both younger and older adult groups. As predicted by the two visual pathways hypothesis (Goodale & Milner, 1992), participants exhibited a strong susceptibility to the Ponzo illusion during estimation trials, wherein objects placed on the “far” surface were consistently judged to be larger, while this effect was not observed during the grasping task. However, the present data also revealed a surprising and intriguing reversal in the direction of the grasping effect: both younger and older participants opened their fingers wider for objects located on the “close” surface compared to the “far” surface.

These results suggest that participants’ grasping behaviour was influenced by some component of the visual display. One plausible explanation for this reversal effect lies in the relative size of the surfaces in the Ponzo illusion board. In particular, the “close” surface in the Ponzo display is physically larger than the “far” surface (Figure 1A). Thus, it is possible that grasping movements were influenced not by the illusory depth per se, but by the visual properties of the surface immediately surrounding the object. For example, the larger size of the close surface may have altered the perceived affordances of the grasping environment, thereby prompting participants to scale their grip differently than we anticipated (Fagg & Arbib, 1998).

Moreover, this effect may be especially pronounced in older adults due to age-related changes in visuomotor integration and strategy selection. Previous research has shown that older adults may exhibit more compensatory, conservative, and variable grasping strategies, often characterized by larger grip apertures and slower movements (Campoi et al., 2023; Cicerale et al., 2014). The data from our study further support this pattern, with older adults demonstrating slower movement times and longer times to peak grip aperture relative to younger adults. These

motor patterns may reflect a compensatory strategy aimed at minimizing risk and ensuring task success. In this context, the visual layout of the close surface may have exerted an exaggerated influence on their motor planning, leading to the observed reversal effect.

To further investigate this possibility, we designed a follow-up experiment that eliminated the illusion-inducing perspective lines of the Ponzo board. Experiment 2 utilized flat, 2D printed surfaces that varied in their physical dimensions but did not generate an illusion of depth (Figure 3). These surfaces retained the essential manipulation of surface size (i.e., a large “close” surface and a small “far” surface) while removing the classic illusory depth cues present in the Ponzo illusion (see Ahsan et al., 2025 for a similar manipulation). The goal was to determine whether the reversed grasping effect observed in Experiment 1 could be attributed to surface size alone.

If grasping behaviour in the Ponzo illusion condition was indeed driven by visual context (e.g., background surface size) rather than by the illusion itself, then we would expect to observe a similar pattern in Experiment 2; that is, larger grip apertures for objects on the bigger (“close”) surface, even in the absence of an illusion. Conversely, if the reversed effect was truly an anomalous illusion-based phenomenon, it should disappear when the illusory cues are removed.

## Experiment 2

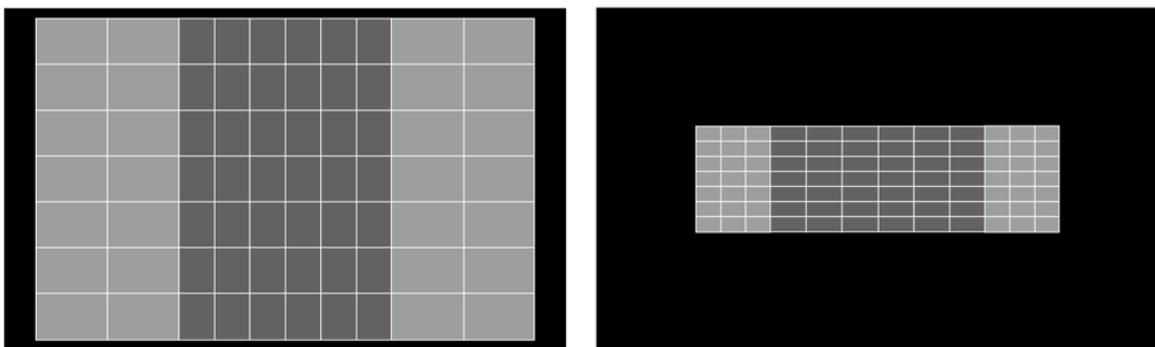
### Methods

#### *Participants*

Twenty-five younger adults (15 female;  $M = 20.60$  years,  $SD = 2.20$ , range = 18–25) and twenty-five older adults (21 female;  $M = 75.80$  years,  $SD = 4.76$ , range = 68–87) participated in Experiment 2. Participant eligibility, screening criteria, and recruitment procedures were identical to Experiment 1. All participants provided informed consent and received either course credit (younger) or monetary compensation (older). Some younger ( $n = 4$ ) and older ( $n = 14$ ) adults participated in both experiments, with a 10-month gap between sessions.

#### *Apparatus and Stimuli*

The apparatus and procedures mirrored those of Experiment 1, except that the illusion-inducing diagonal lines were removed. Participants performed the same grasping and estimation tasks using the same target objects (40 mm and 42 mm blocks). However, objects were presented on flat surfaces that mimicked the spatial layout of the Ponzo illusion without inducing depth cues (Figure 3). The “close/bigger” surface was physically larger than the “far/smaller” surface, allowing us to isolate the role of surface size in modulating visuomotor behaviour.



**Figure 3.** *Experimental set-up.* On the left is the “close”, *bigger* surface, and on the right is the “far”, *smaller* surface.

### ***Design and Procedure***

Each participant completed 60 grasping trials and 60 estimation trials. The task structure, randomization, and trial sequence were identical to those in Experiment 1. The order of tasks was counterbalanced across participants. In grasping trials, participants picked up the object with their index finger and thumb. In estimation trials, they extended their thumb and index finger to match the perceived length of the object without touching it.

### ***Data Analysis***

Data recording, processing, movement onset/offset definitions, and normalization procedures were identical to those in Experiment 1. The only difference was the independent variable of interest: instead of computing the effect of the illusion, we computed the effect of surface size, measured as the difference between “small” and “big” trials. Positive values indicated larger responses for objects on the small surface. Statistical analyses (ANOVAs and t-tests) examined effects of surface size, object size, and group.

### **Results**

#### ***Perception–Action Dissociation***

To examine whether surface size influenced perception and action differently, a mixed-design ANOVA with task, surface size, and group was conducted on estimation values and adjusted MGA values. This analysis revealed a significant interaction between task and surface size [ $F_{(1, 48)} = 20.53, p < .001, \eta_p^2 = .300$ ], indicating a dissociation: grasping was modulated by surface size, whereas estimation was not (Figure 4A). There was no significant interaction between group, task, and surface size [ $F_{(1, 48)} = 2.55, p = .117$ ], suggesting that the dissociation pattern held across age groups.

Follow-up tests confirmed that grasping responses were significantly affected by surface size: participants opened their fingers wider for objects on the big surface than the small surface [ $F_{(1,48)} = 20.06, p < .001, \eta_p^2 = 0.295$ ]. This surface size effect was evident in older adults [ $t(24) = 4.25, p < .001, d = 0.850$ ], and in younger adults [ $t(24) = 2.06, p = .051, d = 0.412$ ]. Estimation responses were not significantly affected by surface size [ $F_{(1,48)} = 3.30, p = .076$ ].

To further assess how surface size influenced grasping dynamics, we computed the surface size effect (big – small) at each 10% interval from movement onset to offset (Figure 4B). Both age groups showed negative values at mid-to-late movement stages, indicating consistently larger grip apertures for objects on the close surface. No significant group differences were found at any timepoint (all  $ps > .05$ ), reinforcing that both age groups exhibited similar context-related modulation across the reach trajectory.

### ***Age-Related Kinematic Differences***

Similar to the results of Experiment 1, older adults exhibited several motor differences from younger adults. We compared the temporal profile of the grasping movements using an independent t-test that revealed that older adults had longer movement time ( $t = 3.42, p = .001, d = 0.314$ ) and took longer to reach the MGA ( $t = 2.37, p = .022, d = 0.298$ ) (Figures 4C and 4D).

Percent time to MGA, which reflects the proportional temporal structure of the reach, did not differ between groups ( $t = -1.88, p = .066$ ) (Figure 4E). This suggests that although older adults moved more slowly in absolute terms, the amount of time it took for older adults to reach their MGA relative to total grasp time remained constant.

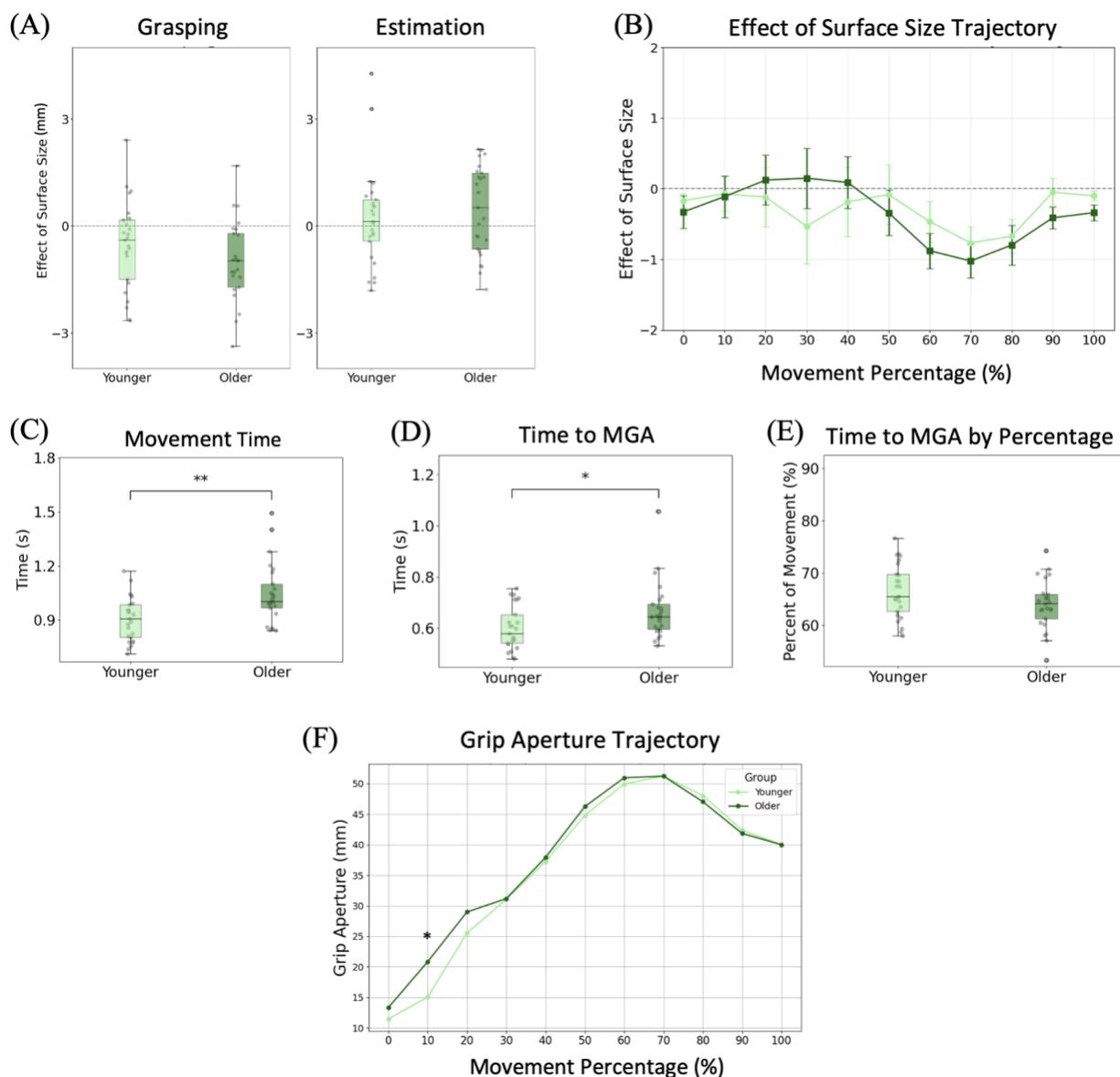
To further explore temporal differences, FDR-corrected t-tests were conducted at each 10% interval of participants' grip aperture trajectories (Figure 4F). A significant group difference was

observed at 10% ( $t = -5.31, p < .001$ ), with older adults showing larger grip apertures early in the reach.

### ***Age Differences Across Both Experiments***

To determine whether the impact of the background context on grasping responses differed by age across the Ponzo illusion and surface-size conditions, a two-way ANOVA between experiment and group was conducted on adjusted MGA values. A significant main effect of group emerged [ $F_{(1, 96)} = 6.01, p = .016, \eta_p^2 = .059$ ], indicating that older adults exhibited stronger “reversed” grasping effects across the two experiments compared to younger adults. There was no significant interaction between group and experiment, [ $F_{(1, 96)} = 0.05, p = .825$ ], suggesting that the age-related difference in grasping was consistent across both experimental conditions.

These findings support the interpretation that older adults are more sensitive to background context during grasping. This is consistent with the proposal that older adults rely more on context during action, potentially as a compensatory strategy to maintain motor accuracy.



**Figure 4.** Results for Experiment 2. (A). Surface size effects for grasping (left) and estimation (right), derived from finger aperture in millimetres, plotted by group. Boxplots represent the effect of surface size (small – big), with individual data points overlaid. (B). Effect of surface size (small – big) plotted across movement time, calculated at 10% intervals from movement onset to offset. (C). Movement time (in seconds) by group. (D). Time to MGA (in seconds) by group. (E). Time to MGA expressed in terms of percentage of the movement. (F). Grip aperture in millimetres plotted across movement time, calculated at 10% intervals from movement onset to offset. Error bars in all figures represent standard error of the mean (SE).

## Discussion

The present study investigated the effect of healthy aging on the perception–action dissociation, as posited by the two visual pathways hypothesis (Goodale & Milner, 1992). Across two experiments, we assessed how illusory and contextual visual information influenced perception (manual estimation) and action (grasping) in younger and older adults. In Experiment 1, participants completed estimation and grasping tasks with blocks placed on the surface of the Ponzo illusion, while in Experiment 2, participants performed the same tasks on backgrounds that mimicked the layout of the illusion, but excluded the illusion-inducing depth cues. Across both experiments, we observed a preserved perception–action dissociation in both younger and older adults, as well as distinct age-related differences in visuomotor behaviour and contextual sensitivity.

### Preserved Perception-Action Dissociation

In Experiment 1, estimation responses were biased in the expected direction of the Ponzo illusion: objects placed on the “far” surface were perceived as longer than identical objects placed on the “close” surface. However, grasping responses were not unaffected by the illusion, as typically expected. Instead, participants opened their fingers slightly wider when grasping objects on the “close” surface: a surprising deviation from the typical immunity of grasping to the Ponzo illusion, and a reversal of the usual direction of perceptual bias.

In Experiment 2, we tested whether this reversed effect could be explained by the physical surface size rather than illusory depth cues. Indeed, when only surface size was manipulated, grasping responses again showed this modulated effect, with larger grip apertures for objects placed on the “big” surface rather than the “small” surface (especially in older adults),

while estimation responses were unaffected. Together, these results provide strong behavioural evidence that perception and action are functionally dissociable in both younger and older adults.

Despite well-documented age-related declines in cognitive, visual, sensory, and motor functions (Cicerale et al., 2014; Grady, 2012; Swenor et al., 2019), our results demonstrate a functional segregation between perception and action in healthy aging. These findings stand in contrast to the dedifferentiation hypothesis, which proposes that aging leads to reduced neural selectivity and a blurring of functional distinctions between cognitive and sensorimotor systems (Park et al., 2004). If dedifferentiation had weakened the distinction between perception and action, older adults would have been expected to show similar biases across both the grasping and estimation tasks in Experiment 1. Instead, we observed a clear dissociation between perception and action in both age groups.

This finding aligns with extensive prior literature showing that visually guided grasping is often resistant to the distortions induced by visual illusions that reliably bias perceptual judgments (Aglioti et al., 1995; Ganel et al., 2008b; Ozana & Ganel, 2020). While most previous studies have focused on younger adults, the present results extend this pattern to healthy aging to show that the perception–action dissociation remains robust across age groups, even as other aspects of visuomotor control may change.

Notably, recent neuroanatomical research has refined our understanding of the dorsal visual pathway by identifying sub-pathways within it. Rizzolatti and Matelli (2003) established a subdivision within the dorsal stream: a ventro-dorsal stream, including MT and visual areas of the inferior parietal lobule, and a dorso-dorsal stream, which includes areas V6, V6A and medial intraparietal areas (MIP). According to their description, the ventro-dorsal stream is involved both in perception and in action, while the dorso-dorsal stream is specifically involved in motor

tasks. This subdivision may help explain why our findings show preserved dissociation in aging, as the dorso-dorsal stream (responsible for the most direct guidance of actions) appears to maintain its functional integrity, despite broader age-related changes.

It is important to recognize that grasping is not categorically immune to illusion effects. Recent work has demonstrated that conscious monitoring of grasping movements can make them more susceptible to perceptual intrusions. Navon and Ganel (2020) showed that consciously monitored grasping is vulnerable to perceptual intrusions, demonstrating that when participants were required to stop their grasp early (before object contact), their grip apertures became biased by the Ponzo illusion. This finding suggests that the timing and conscious monitoring of grasping movements can modulate the perception-action dissociation. In our study, participants completed full grasping movements with object contact, which may explain why we observed resistance to illusory bias in the traditional sense, while still finding sensitivity to physical surface context.

From a theoretical standpoint, these findings support the view that functional dissociation between perception and action is preserved in aging, despite broader cognitive and motor declines. While conclusions cannot be drawn about neural ventral–dorsal dissociation without direct imaging data, the behavioural patterns observed here strongly suggest that the underlying computations guiding perception and action remain separated in older adulthood.

### **Understanding the Reversed Grasping Effect**

The reversed grasping effect we observed—where grip apertures were larger for objects on the physically larger, close surface—warrants further explanation. Because this pattern emerged even in the absence of illusory depth cues (Experiment 2), it likely reflects a visuomotor sensitivity to physical surface layout, rather than susceptibility to perceptual distortion. One potential explanation for this effect relates to the spatial proximity of visual borders. In both

experiments, objects placed on the “close/big” surfaces were positioned farther away from the borders of the background surface, while objects on the “far/small” surfaces were closer to these visual boundaries. This proximity to borders may have influenced grasp scaling through mechanisms related to affordance perception, where the spatial structure of the environment modulates how actions are executed (Cisek, 2007).

The affordance competition hypothesis proposed by Cisek (2007) provides a framework for understanding this effect. According to this view, the cortical mechanisms of action selection involve continuous competition between multiple potential actions based on the affordances present in the visual environment. In our experimental setup, the larger visual surface may have afforded more space for movement execution, leading participants to scale their grip apertures accordingly. This interpretation aligns with embodied cognition theories that emphasize how environmental context shapes motor planning and execution (e.g., Foglia & Wilson, 2013).

### **Altered Visuomotor Behaviours in Aging**

Although both age groups demonstrated a preserved perception–action dissociation, older adults exhibited notable differences in movement dynamics and contextual sensitivity. In both experiments, older adults showed longer movement times and delayed peak grip aperture. These results are consistent with previous work showing that older adults tend to adopt more cautious, variable, and conservative grasping strategies (Caetano et al., 2016; Campoi et al., 2023; Cicerale et al., 2014).

The fact that older adults were more affected by surface size suggests they may rely more heavily on background context during action planning. One possible explanation for this increased sensitivity is provided by the CRUNCH framework (Reuter-Lorenz & Cappell, 2008), which posits that older adults recruit additional cognitive or perceptual resources to compensate

for functional declines. In our study, older adults may have weighted contextual visual information more heavily in order to maintain motor accuracy. Notably, this occurred without a loss of the dissociation between perception and action, further supporting the idea that aging is accompanied by strategic adaptations rather than a breakdown of core processing systems.

Despite the observed slowing and greater modulation by context, percent time to MGA did not differ between groups. This suggests that although the absolute timing of movements changed with age, the temporal structure of the grasping trajectory remained intact. Thus, while older adults modified their visuomotor execution strategies, the fundamental organization of movement planning appeared to be preserved.

### **Age-Related Changes Across Neural Systems**

It is important to consider that the age-related differences we observed in visuomotor behaviour may reflect changes occurring across multiple neural systems. Aging affects both the central nervous system (CNS) and peripheral nervous system (PNS) in distinct ways. While the CNS experiences changes in brain structure, neurotransmitter function, and neural connectivity, the PNS undergoes morphological changes including loss of myelinated nerve fibers, demyelination, and reduced nerve conduction velocity (Verdú et al., 2000).

Peripheral nerve aging is characterized by axonal atrophy, reduced expression of myelin proteins, and decreased regenerative capacity following injury. These changes in the PNS result in decreased sensation, slower reflexes, and reduced motor precision. As such, the PNS may be particularly vulnerable to age-related changes because peripheral nerves lack the protection of the blood-brain barrier and may be more susceptible to toxic metabolites and inflammatory mediators that accumulate with age. The slower movement times and altered grasping kinematics

we observed in older adults may therefore reflect the combined influence of both central processing changes and peripheral motor system deterioration.

### **Implications for Real-World Functioning**

Our findings have important implications for understanding how older adults navigate their daily environments. The increased sensitivity to contextual visual information we observed may represent both an adaptive strategy and a potential vulnerability. While relying more heavily on environmental cues may help compensate for age-related sensory and motor declines, it may also increase susceptibility to misleading visual information.

For instance, research has demonstrated that complex patterns on carpets, floors, or stairs constitute an extrinsic factor contributing to fall accidents in older populations (Lu et al., 2021). Additionally, patterned surfaces can cause visual discomfort, and are associated with nausea and migraines (Bonato et al., 2011; Wilkins et al., 2018). Given that visual impairments are a recognized risk factor for falls (Ivers et al., 2000), these environmental factors become particularly concerning for older adults with age-related vision changes and altered visuomotor processing.

Walking on patterned surfaces may negatively impact gait, balance, and spatial orientation (McNeil & Tapp, 2015), creating challenges for environmental recognition and navigation. Our findings suggest that while older adults' increased reliance on contextual visual cues may serve a compensatory function, it may also make them more vulnerable to misleading or irrelevant environmental information, making it difficult to effectively organize and interpret visual signals and potentially resulting in incorrect perceptions and cognitive biases.

## **Limitations**

While the present study offers novel insights into the perception–action dissociation in aging, several limitations should be considered. First, one important limitation is the inability to determine whether the apparent functional dissociation between perception and action represents changes in the neural dissociation between the ventral and dorsal visual pathways. Future work using neuroimaging methods such as fMRI or EEG would allow researchers to investigate whether altered recruitment of dorsal and ventral networks underlies age-related differences in grasping strategy, or if these effects are primarily behavioural.

Second, although older adults frequently exhibit age-related visual impairments (e.g., cataracts, glaucoma), we excluded participants with uncorrected vision issues, and all older participants demonstrated normal or corrected-to-normal acuity. More detailed assessments of contrast sensitivity, depth perception, and stereopsis could potentially help to further isolate perceptual contributions to age-related grasping behaviour.

Third, while grasping and estimation tasks were carefully controlled, we did not collect eye-tracking or gaze data. Eye movement patterns, especially in older adults, may provide insights into compensatory scanning strategies or altered saliency prioritization that contribute to enhanced context sensitivity.

## **Conclusion**

The present study examined how healthy aging modulates the dissociation between perception and action using a Ponzo illusion paradigm and a matched surface-size manipulation without illusion cues. Across both experiments, we found strong evidence for a preserved perception–action dissociation in older adults, supporting the continued functional segregation of ventral and dorsal visual pathways.

However, older adults also exhibited altered behavioural patterns, including slower movements and enhanced sensitivity to contextual surface features during grasping. These results suggest that aging alters visuomotor strategy, possibly as a compensatory mechanism, without affecting the underlying neural architecture that supports perception and action as distinct processes. At the same time, increased reliance on background visual features (such as surface size) highlights potential vulnerabilities in real-world settings where complex or misleading visual patterns may interfere with accurate action guidance.

Taken together, these findings advance our understanding of visuomotor aging, revealing that while core functional systems remain intact, older adults may rely more on environmental cues to guide action. This highlights the importance of studying not only whether cognitive and sensorimotor functions are preserved in aging, but also how the brain adapts to maintain performance in the face of structural decline. Understanding these adaptive mechanisms has important implications for environmental design and safety considerations for aging populations.

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