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Age-related decline in global form suppression

Iris Wiegand[a,b,c,*], Kathrin Finke[a], Thomas Töllner[a,c], Kornelija Starman[a], Hermann J. Müller[a,d], Markus Conci[a]

[a] Department of Psychology, Ludwig-Maximilians-Universität München, Leopoldstr. 13, 80802 München, Germany
[b] Center for Visual Cognition, Department of Psychology, University of Copenhagen, Øster Farimagsgade 2A, 1353 København, Denmark
[c] Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, Großhaderner Str. 2, Planegg-Martinsried, 82152, Germany
[d] School of Psychological Sciences, Birkbeck College, University of London, Malet Street, London WC1E 7HX, UK

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ABSTRACT

Visual selection of illusory 'Kanizsa' figures, an assembly of local elements that induce the percept of a whole object, is facilitated relative to configurations composed of the same local elements that do not induce a global form—an instance of 'global precedence' in visual processing. Selective attention, i.e., the ability to focus on relevant and ignore irrelevant information, declines with increasing age; however, how this deficit affects selection of global vs. local configurations remains unknown. On this background, the present study examined for age-related differences in a global-local task requiring selection of either a 'global' Kanizsa- or a 'local' non-Kanizsa configuration (in the presence of the respectively other configuration) by analyzing event-related lateralizations (ERLs). Behaviorally, older participants showed a more pronounced global-precedence effect. Electrophysiologically, this effect was accompanied by an early (150–225 ms) 'positivity posterior contralateral' (PPC), which was elicited for older, but not younger, participants, when the target was a non-Kanizsa configuration and the Kanizsa figure a distractor (rather than vice versa). In addition, timing differences in the subsequent (250–500 ms) posterior contralateral negativity (PCN) indicated that attentional resources were allocated faster to Kanizsa, as compared to non-Kanizsa, targets in both age groups, while the allocation of spatial attention seemed to be generally delayed in older relative to younger age. Our results suggest that the enhanced global-local asymmetry in the older age group originated from less effective suppression of global distracter forms on early processing stages—indicative of older observers having difficulties with disengaging from a global default selection mode and switching to the required local state of attentional resolution.

1. Introduction

Attentional selection of visual information becomes slower and more error-prone in older age (Madden, 2007). The degree of age-related decline, though, depends on the particular conditions and type of visual information, with older participants finding it especially hard to ignore task-irrelevant stimuli that provide strong attractors for visual attention (McDowd, 1997; Mevorach, Humphreys, & Shalev, 2006).

Illusory figures consist of fragments that are perceived as whole objects. For example, Kanizsa figures (Kanizsa, 1976) induce the percept of a global shape (e.g., a square; see Fig. 1, right) from local inward-facing 'pacman'-type inducer stimuli, whereas no coherent global form is perceived when the same local inducers face outwards (see Fig. 1, left). This type of global shape integration is generally thought to be an automatic process, originating from early processing stages (see Murray and Herrmann, 2013; for a recent review). Accordingly, there is a processing advantage for global relative to (in terms of the inducers elements: physically identical) local configurations, suggesting that visual scenes, by default, are interpreted initially on a global hierarchical level (Hochstein and Ahissar, 2002). As for Kanizsa-type configurations, global stimuli generate a strong bottom-up signal for visual selection, evidenced by the fact that they are detected equally efficiently irrespective of the number of non-Kanizsa-stimuli in the search display ("pop-out" effect; Davis and Driver, 1994). In turn, when the task requires attention to be directed towards local (rather than global) elements, participants' control settings need to be adjusted so that now task-irrelevant global signals can be suppressed (Rauschenberger and Yantis, 2001). Of theoretical importance, this search benefit for Kanizsa relative to non-Kanizsa targets has been demonstrated to derive primarily from the extraction of a closed region (i.e., a global surface), rather than specification of the bound-

* Corresponding author at: Center for Visual Cognition, Department of Psychology, University of Copenhagen, Øster Farimagsgade 2A, 1353 København, Denmark.
E-mail addresses: iris.wiegand@psy.ku.dk, iris.wiegand@gmx.de (I. Wiegand).

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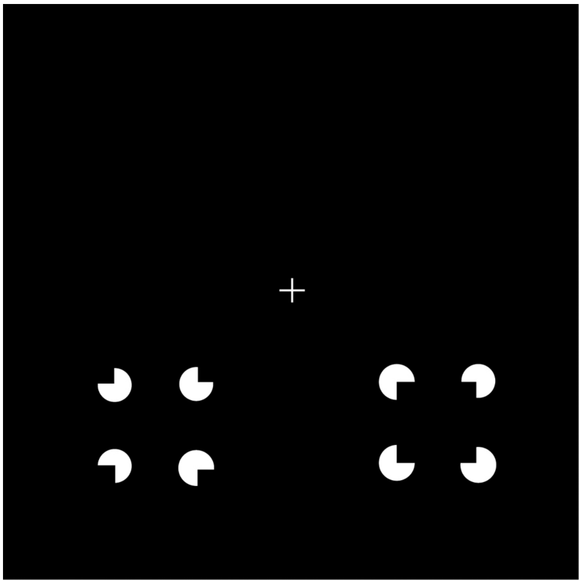

Fig. 1. Task display.
Example of a target-present display that shows the two possible stimulus locations in the experiment. In the global task, the target was a Kanizsa square (right) and the corresponding distracter was the non-Kanizsa configuration (left). Conversely, in the local task, the non-Kanizsa configuration was the target, and the Kanizsa square was the distracter. Target-absent displays would always present two distracters, either two Kanizsa squares or two non-Kanizsa configurations, depending on the local or global task, respectively.

ing illusory contours (Conci, Gramann, Müller, & Elliott, 2006; Conci, Müller, & Elliott, 2007; Conci et al., 2009).

Although selection of global illusory figures vs. local configurations would, thus, provide a powerful manipulation for examining age-related changes in attentional selectivity, there are no studies to date that have systematically explored its effects. According to the inhibition-deficit theory of aging (Hasher, Lustig, & Zacks, 2007), one might expect older, as compared to younger, adults to display increased difficulty to select a local configuration, and suppress a task-irrelevant global object. Indeed, age-related decline in inhibitory processes has been suggested to account for age-dependent changes in the global-local processing of other, Navon-type (Navon, 1977) hierarchical stimuli (Tsvetanov, Mevorach, Allen, & Humphreys, 2013). However, recent findings suggest that the increased global processing advantage (or local processing disadvantage) with age is rather task-specific and not consistent across different global-local paradigms (Lux, Marshall, Thimm, & Fink, 2008; Staudinger, Fink, Mackay, & Lux, 2011)—arguing against an account of age differences in global-local processing in terms of a general deficit of inhibitory control in older adults (Bruyer and Scailquin, 2000). Thus, from the available literature, it remains controversial what type of neuro-cognitive mechanisms contribute to the ostensibly relatively specific age effects on global-local processing (Georgiou-Karistianis et al., 2006).

In younger participants, recent neuroimaging studies provided deeper insights into the neural substrates of global-local processing (Murray and Herrmann, 2013; Seghier and Vuilleumier, 2006). In particular, activations in the lateral occipital complex (LOC) have been linked to the processing of coherent objects, and preferential processing of closed shapes via feedback to lower-level striate and extrastriate visual areas (Altschuler et al., 2012; Murray et al., 2002; Lee and Nguyen, 2001; Stanley and Rubin, 2003). In addition, event-related potentials (ERPs) provide a complementary view of the temporal processing dynamics of illusory-figure processing and a means to investigate how pre-selective global shape integration influences subsequent attentional processing stages. ERPs in response to illusory figures start to differ in the time range of the posterior N1, which is typically enhanced for Kanizsa figures compared to local-level baseline configurations (e.g., Herrmann and Bosch, 2001; Murray, Foxe, Javitt, & Foxe, 2004; Proverbio and Zani, 2002; Senkowski, Röttger, Grimm, Foxe, & Herrmann, 2005; see Murray et al., 2002, for even earlier effects). In accordance with the imaging literature, the global-local N1 effect has been interpreted to reflect global shape processing in the LOC (He, Fan, Zhou, & Chen, 2004; Martinez, Ramanathan, Foxe, Javitt, & Hillyard, 2007; Murray, Imber, Javitt, & Foxe, 2006). This initial processing advantage for global shapes, as reflected in the N1, has been suggested to influence the attentional priority assigned to competing objects under visual selection conditions (Senkowski et al., 2005). In a subsequent time window, the actual spatial-attentional selection of global vs. local configurations is indexed by the posterior contralateral negativity (PCN; Conci et al., 2006; Conci, Töllner, Leszczynski, & Müller, 2011; Töllner, Conci, & Müller, 2015), where the event-related lateralization (ERL) is quantified as the differential activity over the hemispheres contra- vs. ipsilateral to the visual hemifield in which a target stimulus is presented (Corriveau et al., 2012; Luck, Woodman, & Vogel, 2000; Wascher and Wauschkuhn, 1996). The PCN (also referred to as N2pc) is an established ERP marker for focal-attentional selection of task-relevant items in visual space (e.g., Eimer, 1996; Woodman and Luck, 1999; Töllner et al., 2011, 2012a,b), with generators residing in posterior parietal and ventral occipito-temporal cortex (Hopf et al., 2000, Hopf, Boelmans, Schoenfeld, Heinze, & Luck, 2002). For younger participants, we recently showed that the PCN varies with global-local properties of target and distracter stimuli under different selection conditions (Conci et al., 2011). In our study, participants were presented with Kanizsa squares and non-Kanizsa configurations appearing at two possible locations in a bilateral display (see Fig. 1). Participants were instructed to make a target-present vs. target-absent decision under two conditions: In the “global” condition, participants had to detect the Kanizsa figure and ignore the non-Kanizsa distracter. In the “local” condition, participants were presented with identical stimuli, but now had to detect the non-Kanizsa target configuration while ignoring the Kanizsa figure distracter. A behavioral global-precedence effect – that is: faster and more accurate selection of global as compared to local targets – was accompanied by an earlier peaking PCN in the global compared to the local task, indicative of a faster shift of focal attention to the target when the global target had to be detected, compared to when the local configuration was the target.

In the present study, we adopted the approach introduced by Conci et al. (2011) to provide deeper insight into the mechanisms underlying age differences in global-local processing. We assessed behavioral performance measures (reaction times [RTs] and response error rates [ERs]) and ERLs[1] of groups of younger and older adults in tasks in which either Kanizsa-squares were targets and non-Kanizsa configurations distracters, or, conversely, non-Kanizsa configurations were targets and Kanisza-squares distracters. Besides a general decline in performance with age (Salthouse, 1996), we expected qualitative differences between younger and older adults to become manifest in terms of an over-additive influence of global-local task conditions on age effects (Age × Task interaction). Following our previous study (Conci et al., 2011), we expected global precedence, and potential age differences in this effect, to be mirrored in the PCN. To preview the main results, as hypothesized, we observed a global-local PCN

[1] As we were specifically interested in effects of age on the attentional selection of global vs. local stimuli, we focused on ERLs; see the Supplement for analyses of non-lateralized effects on visual ERPs.