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We see the orange not the lemon: typicality effects in ultra-rapid categorization in adults with and without autism spectrum disorder

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Semantic meaning can be extracted from pictures presented very briefly, in the order of tens of milliseconds. This ultra-rapid categorization processing appears to respect a coarse-to-fine path where lower level representations of concepts, or more detailed information, need additional time. We question whether variations in the levels of typicality of the target-item would implicate additional processing for correct classification, both in neurotypical (NT) individuals and with autism spectrum disorder (ASD). Previous research in ASD points out that atypical exemplars of a category might be abnormally processed (e.g., longer times in identifying a penguin as a bird), an observation that we further tested with a rapid serial visual presentation (RSVP) task. In this study, we applied a RSVP task, with four different presentation times (13, 27, 50, and 80 ms) and with typical and atypical exemplars to a group of NT individuals and a sample of individuals with ASD. We found, overall, a strong effect of typicality with a higher detection rate for typical items. In addition, we observed a group × typicality × duration interaction. We interpret these findings in the light of the competences of the feedforward sweep of information through our visual system.

People have the ability to detect meaning on a single glance. One of the first observations of this extremely fast, high-level processing of the visual system comes from a study of Thorpe, Fize, and Marlot (1996). In this study, healthy participants performed a go/no-go categorization task in which they had to decide whether a picture of a natural scene, flashed on for just 20 ms, contained an animal or not. The average correct detection found was as high as 94% and this behaviour was correlated with a frontal differential neurophysiological activity developed at about 150 ms from stimulus onset. The average

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response times (RTs), which includes the motor response, was of 445 ms (Thorpe *et al.*, 1996).

Numerous studies have since been reporting on this fast visual categorization ability, and similar results can be found, for instance, with biological non-relevant stimuli (VanRullen & Thorpe, 2001a,b); with novel as well as extensively trained images (Faber-Thorpe, Delorme, Marlot, & Thorpe, 2001); and with unusual representations of stimuli (Guyonneau, Kirchner, & Thorpe, 2006).

Other studies, however, put a limit to this fast visual processing (Faber-Thorpe, 2011). Studies where different conceptual levels (i.e., superordinate, basic) were directly and systematically compared (Fei-Fei, Iyer, Koch, & Perona, 2007; Macé, Joubert, Nespoulous, & Faber-Thorpe, 2009) support the view that lower level categorization needs additional processing time. When comparing categorization processing of superordinate level with that of basic-level concepts, participants performed with greater accuracy for the higher, more coarse representation (Fei-Fei *et al.*, 2007) and needed an additional 45–60 ms to correctly respond to basic-level concepts (Macé *et al.*, 2009). Faber-Thorpe (2011) thus propose a coarse-to-fine hypothesis, positing that categorization levels are reached from superordinate to basic and subordinate categories.

Critically, these findings on ultra-rapid categorization processing suggest that participants must be essentially relying on feedforward activity through the ventral visual pathway, at least for coarse object representations at the superordinate category level (Faber-Thorpe, 2011; Thorpe & Faber-Thorpe, 2001).

These feedforward sweeps of information are characterized by relaying information from lower to higher visual cortical areas, in a cascade of successive hierarchical levels. Somewhere along this path, there is the ventral and dorsal stream bifurcation (Lamme & Roelfsema, 2000). Together with this mechanism, there are also feedback or re-entrant loops that play a prominent role in visual functioning. After a while, the information from feedback connections, which go in the reverse direction, can be incorporated in the responses of visual cortical neurons, changing their tuning, at any hierarchy level; thus contributing to different analysis at different moments in time. These re-entrant connections are additionally hypothesized to be a necessary condition for conscious experience (Lamme, 2006; Lamme & Roelfsema, 2000)

A recent study supports the idea that feedforward processing seems sufficient for conceptual apprehension of complex visual information (Potter, Wyble, Hagmann, & McCourt, 2014). In this study, participants performed a rapid serial visual presentation task (RSVP) in which pictures were presented for as brief as 13 ms (up to 80 ms). Results show that the detection rate was above chance for all presentation durations, and even when the prompt category was presented only after the sequence of stimuli. For the authors, the fact that healthy individuals can identify and extract meaning from pictures in less than 50 ms, that is the minimum time necessary for a feedback loop to be completed, challenges and extends the competences of a single forward pass of processing (Potter *et al.*, 2014).

A couple of studies have, recently, evaluated this ultra-rapid categorization processing in both children and adults with autism spectrum disorder (ASD) (Hagmann *et al.*, 2016; Vanmarcke *et al.*, 2016). In one of these studies (Vanmarcke *et al.*, 2016), participants were shown images of natural scenes (for 33 ms) and had to respond, for instance, whether they saw either an animal or a vehicle in the pictures presented earlier. The comparison between the group of adults diagnosed with ASD and matched control participants showed no differences in either accuracy or RTs for that task.

In another study (Hagmann *et al.*, 2016), ultra-rapid visual processing was assessed in children with a category task that used letters and numbers as stimuli. Again, no differences were observed between the group of children with ASD and neurotypical (NT) children, for any presentation time (50, 83.3, and 116.7 ms). Together, these two studies argue against a deficit in ultra-rapid categorization processing in this population.

Regardless of the fact that there is still an ongoing debate about the abilities of individuals with ASD to form and acquire new categories (see for instances, Church *et al.*, 2010; Froehlich *et al.*, 2012; Molesworth, Bowler, & Hampton, 2005), there is now a set of studies (Carmo, Duarte, Pinho, Filipe, & Marques, 2016; Gastgeb, Strauss, & Minshew, 2006;) that suggest that individuals with ASD might have an abnormal and narrowed content of natural existing categories, with difficulties arising when processing items that fall at the categories boundary. These studies have evaluated semantic typicality and have found, in this population, an anomalous processing of atypical items (e.g., detecting *penguin* as a *bird*) in comparison with a regular processing of typical instances of a given category.

The distinction between different hierarchical semantic levels has long been acknowledged in the field and is central to most models of processing in and organization of the semantic system. Higher level categories are formed in a way that maximizes distinctiveness and discontinuity between different categories: most attributes are common to all members in a given category, and few attributes are shared across different categories. Under the superordinate category level (e.g., animal) comes the basic level (e.g., dog), which is generally the most useful level of classification. Below this level, any further subdivision (subordinate level, for example German shepherd) will add little information (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976).

To the best of our knowledge, no studies in ultra-rapid categorization have dealt with the impact of the level of semantic typicality on categorization and identification of visual material. For Martinovic, Gruber, and Muller (2008), superordinate identification can occur with less information and detail, while basic and subordinate level classification rely on additional features. When taking the level of typicality of an item into account it could be expected that typical instances will be categorized at the basic level (i.e., sparrow as a bird) whereas atypical exemplars, with distinct attributes, will be recognized at a subordinate level (e.g., an ostrich).

The current study was designed in order to evaluate the influence of the level of typicality in the detection of basic-level representations in pictures presented for as briefly as 13 ms. We have closely replicated the study of Potter *et al.* (2014) in which a RSVP paradigm was used, and six pictures, in a sequence, were presented to the participant for 13, 27, 53, and 80 ms. In our study, however, target-items could either be typical instances or atypical instances of a category. Moreover, we tested not only a group of NT individuals but also a group of high-functioning young adults with ASD. In line with the coarse-to-fine hypothesis, we predicted that atypical items would need additional time to be identified as their representation might need to be processed at the subordinate level, and as a consequence, detection rate would drop at least for the shortest presentation durations. For individuals with ASD, given the previous reports on abnormal processing of atypical items, we expected that at any presentation time the detection level of those exemplars would be much lower than for the NT group.

Methods

Participants

Fourteen (2 females) NT participants and 16 (4 females) participants with ASD took part in the experiment. The two groups were matched for age, schooling, and general cognitive ability (see Table 1 below). The latter was assessed using Raven's progressive matrixes. Participants with ASD were selected if they were at least 18 years old, had more than 9 years of formal education, scored above 70 points in the verbal subscale of the Wechsler Adult Intelligence Scale, and had been diagnosed with ASD. The diagnosis of autism was based on DSM-IV criteria (American Psychiatric Association, 1994), and the Asperger's Syndrome Diagnostic Scale (ASDS, Myles, Bock, & Simpson, 2001) was used to confirm the clinical evaluation diagnosis.

Written informed consent was obtained from each participant prior to any experimental procedure.

Materials and procedure

All participants viewed sequences of six pictures presented in a Toshiba laptop (screen refresh rate of 40 Hz) for either 13, 27, 50, or 80 ms in each sequence, and at the end of each sequence they were asked to identify a target-item belonging to a basic-level category (see Figure 1). Target-items could fall into four categories: mammals, birds, vehicles, and fruits. There were 48 critical trials in which a target-item was presented and 24 trials in which no picture of a target-item was presented. Half of the critical trials contained a typical target-item and the other half an atypical target (see Appendix Table A1).

Each participant completed four blocks with 18 trials (six atypical, six typical, and six non-target trials), of each category. In each block, the pictures' sequences were presented for 13, 27, 50, or 80 ms, and the order of the blocks was randomly assigned to each subject. We used a latin-square procedure, counterbalanced across subjects, to make sure that all categories were presented the same amount of times with each of the four different presentation durations. The target pictures appeared in the sequence in the positions 2, 3, 4, or 5 and this was counterbalanced across trials. Participants completed a practice block, with eight trials, in which pictures were presented for 133 ms. The pictures were taken from the web and were colour photographs, of living and non-living things, with a blank background, and each picture was presented only once. The typicality level was based on typicality ratings taken from Santi, Raposo, and Marques (2015). Independent sample *t*-tests confirmed that the typicality ratings were significantly different between the typical and atypical sets (typical items: $M = 1.27$, $SD = 0.21$, atypical items: $M = 3.74$, $SD = 0.9$, $p < .001$).

Each trial began with a fixation cross displayed for 1,000 ms, followed by a blank slide for 200 ms and then the sequence of pictures was presented. A blank screen of 200 ms

Table 1. Demographic information of both groups of participants. Mean and standard deviation are provided for each group

	NT	ASD	*p* values
Age	23.43 (5.26)	26.94 (5.49)	.08
Schooling	13.64 (1.55)	13.25 (2.11)	.57
Raven (raw scores)	51.21 (6.18)	47.69	.20

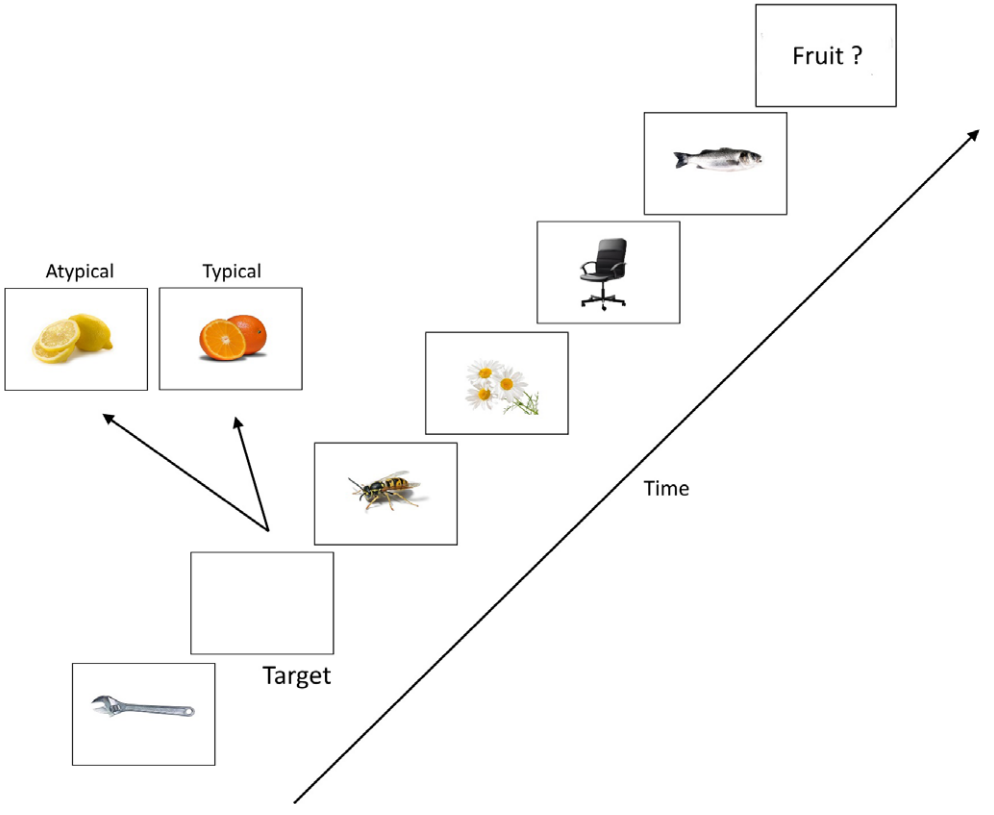

Figure 1. Schematic depiction of a trial. The target-items could be typical or atypical of the target category. In each trial, picture were presented for either 13, 27, 50, or 80 ms. Target picture could appear in the second position (as depicted) or in 3rd, 4th or 5th.

followed the sequences at the end of which a slide with the question 'Have you seen a [category label]?' appeared, and subjects were asked to press and answer Y (yes) or N (no) on the keyboard. Participants' responses were self-paced.

Statistical analyses

For the main results, repeated measures ANOVAs were run for participants' *d' (z* score of Hits minus *z* score of False alarms), as a function of presentation duration (13, 27, 50 and 80 ms), typicality (typical and atypical items), and with group (ASD and NT) as a between-subjects factor. The Shapiro wilk test for normality was run but no results were significant (all *p*s > .001). Independent sample and paired *t*-tests were run afterwards to understand the main and interaction effects found. Similar ANOVAs were also run for *c* (sum of *z*-scores of Hits and False alarms) and RT measures in order to check for biases and trade-off effects.

Results

Regarding the sensitivity *d'* parameter, results (Figure 2) showed a main effect of Presentation duration ($F(3,81) = 7.787, p < .001, \eta_p^2 = .21$) as detection improved with increasing duration of the stimuli (13 ms: $M = -0.27$, $SEM = 0.19$; 27 ms: $M = -0.31$, $SEM = 0.21$; 53 ms: $M = 0.12$, $SEM = 0.18$; 80 ms: $M = 0.43$, $SEM = 0.19$). A main effect of Typicality was also found to be significant with superior detection of typical items ($M = 0.49$, $SEM = 0.18$) than atypical ones ($M = -0.52$, $SEM = 0.14$) ($F(1,27) = 136.845$, $p < .001$, $\eta_p^2 = 0.83$). This effect of the level of typicality was observed for every duration (13 ms: $t(29) = 5.83$, $p < .001$, Cohen's $d = 1.09$); 27 ms: $t(29) = 4.97$, $p < .001$, *Cohen's* $d = 0.96$; 50 ms: $t(29) = 6.83$, $p < .001$, Cohen's $d = 0.84$; 80 ms $t(29) = 5.79$, $p < .001$, Cohen's $d = .071$). The three-way interaction Group × Typicality × Presentation duration ($F(3,81) = 3.281$, $p = .025$, $\eta_p^2 = 0.10$) showed a significant effect as well. No other results were found significant. In order to better understand the interaction effect found, subsequent independent samples *t*-tests were run. This comparison between NT and ASD groups showed no significant results (atypical, 80 ms: $t(28) = 2.733$, $p = .011$, Cohen's $d = 1.03$; all other ps $> .29$; with FDR correction).

The analysis of Bias (*c* parameter) showed that there are no differences in this parameter between participants with ASD and NT ones (all ps $> .21$).

Regarding RTs, a main effect of Typicality was observed, $F(1, 15) = 6.049$; $p = .027$; $\eta_p^2 = .29$ = with a slower response for atypical items ($M = 1{,}788.15$; $SEM = 164.15$) than for typical items ($M = 1{,}454.28$; $SEM = 86.73$). Thus, not only atypical items lead to overall a lower detection they lead also to a slower response by the participants. A main effect of group was also found ($F(1,15) = 208.157$; $p < .001$; $\eta_p^2 = 0.28$) with NT participants responding faster ($M = 1{,}350.67$; $SEM = 154.17$) than the participants with ASD ($M = 1{,}891.76$; $SEM = 163.52$).

The analysis of chance performance of NT participants showed that detection rate is above 0 only for typical items presented for 50 ms ($t(13) = 2.318$, $p = .037$) and 80 ms ($t(13) = 4.970$, $p < .001$) and for atypical items only at the longest presentation duration (80 ms: $t(13) = 2.330$, $p = .037$). For participants with ASD, performance above chance level was observed for typical items presented for 50 ms ($t(15) = 2.314$; $p < .005$).

Discussion

The aim of the current study was twofold. First, we wanted to analyse subjects' ability, in an ultra-rapid categorization task, to identify atypical exemplars as compared to typical ones, and to evaluate whether varying the typicality level would have an impact on subject's ability to correctly categorize exemplars across different presentation rates. Secondly, we wanted to assess the performance of participants with ASD in this task, as we

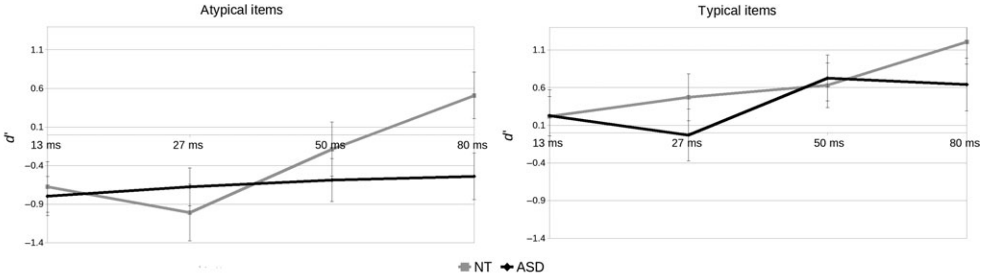

Figure 2. Average of d' measure for NT and ASD groups and for atypical (left plot) and typical target-items (right plot) at four presentation rates. Error bars depict the standard error from the mean.

reasoned that anomalous processing of atypical instances in ASD should be reflected in an impaired ability for fast extraction of categorical information. In the task applied in this study, participants simply had to classify items (from living and non-living domains) according to their superordinate level of belonging (e.g., fruits). The critical manipulation was that the items presented to them were either typical or atypical instances (e.g., orange and lemon, respectively). We predicted that although they could be processed at the same level, atypical instances would need additional time and be processed at a lower hierarchical level for their correct classification. Indeed, we observed a strong effect of the level of typicality in the ability to correctly classify items, with a higher detection rate for typical items. The detection rate differences between typical and atypical exemplars are rather striking and are observable at any duration. Typicality effects are not novel, but within the scope of ultra-fast categorization and the coarse-to-fine hypothesis framework they support the idea that NT participants do not rely on the superordinate category of belonging when processing atypical instances, and that the identification of this particular type of items is only achieved when more detailed and specific information is available, likely due of a later stream of top-down information. The fact that detection of atypical items, which seems to require processing at the basic level of categorization, only occurs at later latencies (i.e., at 80 ms) suggests that for the extraction of information at this level of specificity a single forward pass through the visual system might not be sufficient. Once there is enough time available for top-down information to reach and change the tuning of the visual system neurons, then detection of atypical items becomes possible.

In a study of every day objects (basic-level concepts), Martinovic *et al.* (2008) evaluated colour diagnosticity (objects in their typical colour or not) and have already observed that feature-driven mnemonic effects are a result of later stream processing. The coarse-to-fine effect in ultra-rapid categorization tasks contrasts with vast and classical literature of semantic categorization, in particular with the robust effects of basic-level entry superiority effect in category verification tasks (see for instance ('Is robin a bird?'; Mervis & Rosch, 1981). Some authors have already provided an explanation for this seemingly contradictory findings, and claim that is the influence of factors like context or exposure time that explain the discrepancies between ultra-rapid categorization and category verification tasks. Large exposure times would permit top-down feedback and leads faster categorization of basic-level entries (Mack & Palmeri, 2015). These authors believe also, that default state operates biased towards basic-level categorization.

Our results are nevertheless consistent with the classical literature on semantic typicality where typical items are processed slower in category verification tasks (Smith, Shoben, & Rips, 1974). One limitation of our study is the fact that we cannot compare our performance of ultra-rapid categorization and that of longer exposures to the visual material. Another limitation of our study is that we failed to replicate the finding of Potter (Potter *et al.*, 2014) of detection of stimuli at the shortest presentation rate, but only ate 50 ms and higher participants respond correctly above chance. This could be due to our limited sample, which we could not overcome, or the poor refresh rate. The poor refresh rate could have rendered the fastest presentation (i.e., 13 ms) and the longest one (i.e., 80 ms) later than that designed, this fact as implications as it makes the comparison with the relevant literature, namely the study of Potter *et al.* (2014) slightly inaccurate and importantly makes the 80 ms conditions slightly late (about 100 ms). Despite having an observable main effect of duration of the presentation, the middle presentation rates (i.e., 27 and 50 ms) could be indistinct from each other.

The picture regarding the performance of the ASD sample is slightly more complex. On the one hand, the general effect of typicality can be observed in both healthy participants and in the group of individuals with ASD, which indicates that this distinction between typical and atypical exemplars can be made or is used by both groups.

On the other hand, when taking into account the duration of presentation of stimuli we observed a three-way interaction. Furthermore, for atypical items at 80 ms the detection is above chance only for the NT group and both groups differ in this condition. These outputs have weak statistical power and should be only taken as preliminary so that further studies with increased sample size can lead to a better understanding. Nevertheless, they are indicative and we raise the hypothesis that it could be the feedback loop that is malfunctioning or sluggish in individuals with ASD and is thus responsible for the difficulty of this group to detect this type of items, whereas NT individuals seem, at this latency, already able to do so. A greater dependency of re-entrant loops on long-distance connections could be grounding this faulty processing and would be consistent with the influential under- and hyper-connectivity hypothesis that proposes ASD as a disorder of altered brain functional connectivity (see for instance Di Martino *et al.*, 2014). This hypothesis should be taken with caution and addressed in subsequent studies that directly tackle and examine the functioning of the re-entrant loops.

In sum, we found that atypical items of a given category need extra processing to be correctly identified, which suggests that their correct identification may depend on information from re-entrant connections and we raise the question of whether the difficulties in detecting atypical type of items in ASD, previously reported in the literature, is due to a malfunctioning feedback mechanism.

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Appendix 1

Table A1. List of the target-items used in experiment, by category

Name	Category	Typicality
Donkey	Mammals	Typical
Dog	Mammals	Typical
Chimpanzee	Mammals	Typical
Cat	Mammals	Typical
Lion	Mammals	Typical
Sheep	Mammals	Typical
Mouse	Mammals	Atypical
Hedgehog	Mammals	Atypical
Squirrel	Mammals	Atypical
Otter	Mammals	Atypical
Bat	Mammals	Atypical
Seal	Mammals	Atypical
Eagle	Birds	Typical
Canary	Birds	Typical
Stork	Birds	Typical
Seagull	Birds	Typical
Sparrow	Birds	Typical
Pigeon	Birds	Typical
Penguin	Birds	Atypical
Turkey	Birds	Atypical
Pelican	Birds	Atypical
Goose	Birds	Atypical
Flamingo	Birds	Atypical
Ostrich	Birds	Atypical
Banana	Fruits	Typical
Orange	Fruits	Typical
Apple	Fruits	Typical
Strawberries	Fruits	Typical
Pear	Fruits	Typical
Peach	Fruits	Typical
Avocado	Fruits	Atypical
Olive	Fruits	Atypical
Coconut	Fruits	Atypical
Lime	Fruits	Atypical
Lemon	Fruits	Atypical
Date	Fruits	Atypical
Bus	Vehicles	Typical
Truck	Vehicles	Typical

Continued

Table A1. (*Continued*)

Name	Category	Typicality
Car	Vehicles	Typical
Jeep	Vehicles	Typical
Motorcycle	Vehicles	Typical
Taxi	Vehicles	Typical
Scooter	Vehicles	Atypical
Submarine	Vehicles	Atypical
Skis	Vehicles	Atypical
Wagon	Vehicles	Atypical
Canoe	Vehicles	Atypical
Wheelchair	Vehicles	Atypical