FAST-TRACK REPORT

Rapid naming deficits in dyslexia: a stumbling block for the perceptual anchor theory of dyslexia

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Abstract

According to a recent theory of dyslexia, the perceptual anchor theory, children with dyslexia show deficits in classic auditory and phonological tasks not because they have auditory or phonological impairments but because they are unable to form a ‘perceptual anchor’ in tasks that rely on a small set of repeated stimuli. The theory makes the strong prediction that rapid naming deficits should only be present in small sets of repeated items, not in large sets of unrepeated items. The present research tested this prediction by comparing rapid naming performance of a small set of repeated items with that of a large set of unrepeated items. The results were unequivocal. Deficits were found both for small and large sets of objects and numbers. The deficit was actually bigger for large sets than for small sets, which is the opposite of the prediction made by the anchor theory. In conclusion, the perceptual anchor theory does not provide a satisfactory account of some of the major hallmark effects of developmental dyslexia.

Introduction

Developmental dyslexia is a condition in which children fail to acquire age-appropriate reading skills despite normal intelligence, good educational opportunities and adequate reading instruction (e.g. Snowling, 2000). Although a number of different theories have been proposed to account for dyslexia (for review, see Démonet, Taylor & Chaix, 2004), results from large and well-studied populations confirm that a deficit in phonology is the most robust and specific correlate of dyslexia (e.g. Ramus, Rosen, Dakin, Day, Castellote, White & Frith, 2003; Vellutino, Fletcher, Snowling & Scanlon, 2004; Ziegler, Castel, Pech-Georgel, George, Alario & Perry, 2008). Thus, over recent years, a strong consensus has emerged in support of the phonological deficit theory, according to which the core deficit of dyslexics is due to poor access, memorization and manipulation of phonological information (for reviews, see Goswami, 2002; Vellutino et al., 2004). Deficits in phonological awareness, rapid automatized naming (RAN), verbal short-term memory and phonological decoding are the major hallmarks of the phonological deficit theory (Wagner & Torgesen, 1987). Obviously, access to phonological information plays a pivotal role in learning to read any language because learning to read is primarily based upon the mapping of orthographic onto phonological units. Such phonological decoding skills are the sine qua non of reading acquisition in every language studied so far (for reviews, see Share, 1995; Ziegler & Goswami, 2005, 2006).

One of the strongest attacks against the phonological deficit theory comes from recent work on the perceptual anchor theory of dyslexia (Ahissar, 2007; Ahissar, Lubin, Putter-Katz & Banai, 2006; Banai & Ahissar, 2006). According to the authors, the core deficit does not reside in specific phonological processes but rather in the manner in which these processes have been assessed experimentally. In a critical experiment, Banai and Ahissar (2006) used a same–different task, in which they crossed factorially stimulus complexity (tones versus pseudowords) with task complexity (two versus three items per trial). They found deficits for both tones and pseudowords but only in the complex condition. The authors suggested that task complexity rather than stimulus complexity was causing the deficit of the dyslexics, a finding that was taken as evidence against the phonological deficit theory.

In the search for an explanation of the effects of task complexity, Ahissar et al. (2006) suggested that dyslexics fail to form a perceptual anchor in psychophysical tasks that require the encoding and comparison of several stimuli, such as tones or pseudowords. In a critical experiment, a pair of tones was presented on each trial and participants were asked to decide which of them was higher. In one condition, a reference tone (1000 Hz) was...
presented on each trial, whereas in the other condition no fixed reference tone was repeated across trials. The striking finding was that dyslexics only showed impairments in the ‘reference’ condition, but not in the ‘no-reference’ condition. They argued that while normal readers are able to use the repeated reference tone as a perceptual anchor – a finding that goes back to Harris (1948) – the dyslexics fail to form such a perceptual anchor. As a consequence, dyslexics have to compute a two-tone comparison on every trial, even under conditions in which the general population replaces on-line anchor. As a consequence, dyslexics have to compute a two-tone comparison on every trial, even under conditions in which the general population replaces on-line comparison with stimulus retrieval.

A similar finding was found in the context of speech perception, where participants were asked to repeat a single pseudoword in noisy conditions (Ahissar et al., 2006). In one condition, the authors used a large set of pseudowords without any repetition. In the other condition, a small subset of pseudowords was used and each pseudoword was repeated many times. The authors reported deficits in the small-set condition, whereas no deficit was obtained in the large-set condition. Hypothetically, the deficit was restricted to the small-set condition because dyslexics failed to anchor to repeatedly presented stimuli.

One critical question is how the perceptual anchor theory can account for the hallmark effects of the phonological deficit theory. This has been directly addressed in a recent review article (Ahissar, 2007). The key argument is that most psychophysical or cognitive tasks that are used to assess auditory or phonological deficits rely on massive repetition, which allows unimpaired participants to form perceptual anchors. For example, in speech categorization studies (e.g. Blomert & Mitterer, 2004; Blomert, Mitterer & Paffen, 2004; Godfrey, Syrdal-Lasky, Millay & Knox, 1981; Manis, McBride-Chang, Seidenberg, Keating, Doi, Munson & Petersen, 1997; Serniclaes, Sprenger-Charolles, Carré & Démonet, 2001), participants are asked to categorize speech stimuli that vary on a continuum as belonging to either one or the other category (e.g. /ba/ versus /pa/). According to Ahissar (2007), non-impaired listeners are able to consistently respond to the same stimuli with the same tag because they are able to anchor to recent presentations and their categorizations. Dyslexics, on the other hand, show impaired categorization because they fail to anchor their performance to repeated stimuli. According to the impaired anchor theory, controls and dyslexics should not differ during first encounters but differences should evolve with repeated presentations.

Another hallmark of the phonological deficit theory is rapid naming deficits (e.g. Denckla & Rudel, 1974, 1976). In rapid naming, participants have to name a list of repeated objects, numbers, letters or colors as quickly as possible. Rapid naming is typically subsumed under phonological processes, such as, ‘retention of phonological codes from long-term memory’ (Wagner, Torgesen, Laughon, Simmons & Rashotte, 1993, p. 84) or ‘phonological recoding for lexical access’ (Wagner & Torgesen, 1987, p. 192). For most researchers in the field, rapid naming deficits are ‘part of the phonological family’ (Torgesen, Wagner, Rashotte, Burgess & Hecht, 1997, p. 84). Some have argued that naming deficits are relatively independent from phonological awareness deficits (Wolf & Bowers, 1999), but many studies actually report quite robust correlations between rapid naming and other phonological processes (e.g. Compton, DeFries & Olson, 2001). In addition, a number of studies ruled out an articulatory or visual-attentional locus of the rapid naming deficit (e.g. Di Filippo, Brizolara, Chilosi, De Luca, Judica, Pecini, Spinelli & Zoccolotti, 2005), which suggests that deficits in RAN reflect slow access to phonological representations rather than visual input or phonological output deficits.

According to Ahissar (2007), the perceptual anchor theory can quite naturally account for deficits in RAN because ‘rapid naming tests of figures or digits, in which dyslexics are slower, typically use many repetitions of a small set of items (e.g. ten repetitions on five items). The anchoring deficit predicts that with a large open set, the performance of dyslexics will not differ from that of controls’ (p. 463).

In the present study, we explicitly tested the prediction from the perceptual anchor theory that deficits in RAN should only be present when the task relies on a small set size with repetition but not when a large set size without repetition is used. Indeed, all previous RAN studies used a small set of either objects, colors, letters or numbers, probably because the pioneers of this task (Denckla & Rudel, 1974, 1976) were mainly interested in the issue of skill automatization. Large sets of items have been used in confrontation naming, which showed robust deficits for dyslexics (Swan & Goswami, 1997).

The goal of the present research was to compare the rapid naming of objects and numbers in two conditions. In the small-set condition, a small set of five repeated items was used, just as in the original version of the task. In the large-set condition, an open list of 50 non-repeated stimuli was used. According to the anchor theory, no deficit should be obtained in the large set without repetition. According to the phonological deficit theory, comparable deficits should be obtained in both conditions.

### Methods

#### Participants

The study was part of a research agreement between the University ‘La Sapienza’ and public schools near Rome. Criteria for inclusion in the dyslexic sample were marked reading delay (see below) and performance in the normal range on Raven’s Coloured Progressive Matrices (i.e. above the 10th percentile for age range according to normative Italian data; Pruneti, 1985). Children having indications of severe emotional or attentional problems...
(or any other psychometrically relevant condition) as well as perceptual and language problems were not included in the study. In particular, 25 children were excluded for the following reasons: 10 were foreigners, five stutters, one had strabismus, one had hypo-acousia, and eight children were followed by special teachers because of either general learning problems or emotional/attentional deficits. This procedure led to the identification of 24 dyslexic readers from a total of about 300 children (i.e. 8% of the targeted population). All participants were native Italian speakers. All had normal or corrected to normal visual acuity. Information on age and gender composition and mean performance on Raven's Matrices is presented in Table 1.

A group of 42 Italian, native-speaking readers from sixth grade served as controls for the dyslexic group. These participants were selected from the same schools as the dyslexic readers, thus controlling for neighborhood SES. They performed above the 10th percentile on Raven's Coloured Progressive Matrices. There were no age differences between dyslexics and controls (t(64) = .22, ns). Similarly, there were no differences in performance on the Raven test (t(64) = .22, ns).

As part of the research protocol, the parents received a description of the study and had to approve their child's participation. Subsequently, all information concerning individual performance was considered private and was analyzed strictly for research purposes.

Reading assessment

Reading level was assessed using a standard reading achievement test widely used with Italian children (MT Reading test; Cornoldi & Colpo, 1992a). A meaningful passage was presented, and the participant had to read it aloud (within a 4-min time limit). Time (in sec/syllable) and accuracy (number of errors, adjusted for the amount of text read) were measured. Stimulus materials (and related reference norms) varied depending on school level. Raw scores were converted to z-scores according to standard reference data (Cornoldi & Colpo, 1992b). Based on ICD-10, a z-score of at least 2 standard deviations below the mean of the normative sample was taken as the cut-off. Participants who scored below the cut-off for either speed or accuracy on the MT reading test were included in the reading disabled group. Reading speed and accuracy are presented in Table 1 for both dyslexics and controls. Note that children with dyslexia were particularly impaired in terms of reading accuracy. Reading comprehension was largely spared, which is a typical finding for Italian dyslexics.

Stimuli

Each matrix contained ten rows of five stimuli for a total of 50. All charts were made of white sheet, 21 × 29.7 cm. Two different matrices were generated for each condition; target sequence was randomized within each matrix with the constraint that no more than two identical items could be presented consecutively.

Objects

In the small-set size condition, each matrix was composed of five repeated objects (book, table, needle, bag and house). In the large-set size condition, each matrix was composed of 50 unrepeated objects. All stimuli were ca. 1.5 × 1.5 cm. To check for name agreement and ease of object identification, we carried out a preliminary experiment on a larger set of stimuli with third grade children on the basis of which we selected only objects that were correctly named by at least 90% of children.

Numbers

In the small-set size condition, each matrix was composed of five repeated numbers (2, 4, 5, 7 and 9) generated with Helvetica font (size 36). In the large-set size condition, each matrix was composed of 50 unrepeated numbers ranging between 10 and 99 generated with Helvetica font (size 24). Note that a slightly smaller font size had to be used in the large-set condition to keep overall character size constant.

In sum, there were a total of four naming conditions: (1) Objects small set; (2) Objects large set; (3) Numbers small set; (4) Numbers large set. The conditions were presented in a quasi-randomized order.

Procedure

All participants were tested individually in a quiet room in their school. Stimuli were placed on a flat surface at a distance of about 40 cm from the participant. The task was to name the target as quickly as possible trying not to make errors. The time needed to name each matrix was measured separately for each matrix by means of a stopwatch. Naming errors and omissions were also measured. The tasks were audio-taped and scored offline.

Before each condition, a practice trial was run with a reduced matrix (20 items). In the small-set conditions,
the practice trial was composed of the same items as the experimental trials. However, in the large-set condition, the practice trial was composed of a set of objects and numbers that were not used for the experimental trials. This was done to make sure that there was absolutely no repetition of items in the large-set condition, not even between training and experimental trials (see Ahissar & Oganian, 2008). During training, the examiner corrected any error made by the child. If necessary, the practice trial was repeated.

Results

For all experimental conditions, the performance across the different lists was averaged. Both accuracy (% of errors) and time (seconds per correctly named item) were considered. In general, children were highly accurate: error rates varied from .07 to 1.26% in controls and from .13 to 1.96% in dyslexics. No speed–accuracy trade-off was apparent in the data. Consequently, only the time data were submitted to further analyses. Mean naming times and error rates for the different conditions are presented in Figure 1.

As can be seen in Figure 1, dyslexics exhibited a clear naming deficit for objects and numbers in both the small- and large-set conditions. In fact, the absolute size of the deficit was bigger in the large-set condition than in the small-set condition, which is the opposite of the pattern predicted by the perceptual anchor theory. Individual subject plots showed that the vast majority of the dyslexics showed naming speed deficits (see Appendix). In fact, 20 out of 24 dyslexics were 1.65 standard deviations beyond the mean of the controls in object naming and 18 out of 24 dyslexics were 1.65 standard deviations beyond the mean of the controls in number naming. The dyslexics who were the slowest in the small-set condition were also the slowest in the large-set condition, as indicated by a highly significant correlation of \( r = .80 \) (\( p < .0001 \)). The dyslexics who had the largest deficits in object naming tended to have the largest deficit in number naming, as indicated by a correlation of \( r = .58 \) (\( p < .01 \)). Finally, RAN correlated more strongly with reading speed (\( r = .82 \), \( p < .0001 \)) than with reading accuracy (\( r = .58 \), \( p < .01 \)), which underscores the fact that the dyslexics with the biggest deficits in RAN were also the slowest readers.

The time data were submitted to an analysis of variance with group (dyslexics versus controls) as unreported factor and condition (objects versus numbers) and set size (small versus large) as repeated factors. The group factor was significant \( (F_{(1, 64)} = 61.4, p < .0001) \), indicating slower naming times for children with dyslexia (.97) than controls (.68). The condition factor \( (F_{(1, 64)} = 304.7, p < .0001) \) indicated slower times for objects (1.03) than numbers (.62). The set size factor \( (F_{(1, 64)} = 286.7, p < .0001) \) indicated faster naming times for small- (.65) than large-size (.99) items. The group by condition interaction \( (F_{(1, 64)} = 16.6, p < .0001) \) indicated larger absolute differences between the two groups in the object than in the number condition. The group by set size interaction \( (F_{(1, 64)} = 13.5, p < .001) \) indicated larger differences between the two groups in the large- than in the small-set size conditions. Finally, the condition by set size interaction \( (F_{(1, 64)} = 18.2, p < .0001) \) indicated that the naming time difference between a large- and a small-set size condition was larger for objects (.41) than for numbers (.27).

The finding that large set sizes produce bigger absolute effects than small set sizes is intriguing. However,
this over-additivity could simply be due to the fact that ‘harder’ conditions (i.e. large-set sizes) produce longer overall responses, which then increase the absolute size of the effect. In order to verify whether effect sizes were similar across conditions, we calculated effect size measures (Cohen’s $d$) for each condition. For the objects, the small-set size condition yielded a Cohen’s $d$ of 1.57, whereas the large set size yielded a Cohen’s $d$ of 1.34. For the numbers, the small-set size condition yielded a Cohen’s $d$ of 1.78, whereas the large-set size yielded a Cohen’s $d$ of 1.45. Thus, the overall effect sizes seemed comparable across conditions.

One other way to compare effect sizes across conditions that vary in overall difficulty is to plot the mean of the dyslexics against the mean of the controls for each condition (for a detailed justification, see Faust, Balota, Spieler & Ferraro, 1999). If all points lie on a single regression line, this would suggest that a single global factor explains the deficits between dyslexics and controls. The over-additive pattern would simply be the consequence of the fact that harder conditions produce longer overall latencies, thus giving rise to larger absolute differences but not necessarily larger effect sizes.

To test this prediction, we first plotted the overall condition means against the standard deviations for each condition. As can be seen in Figure 2A, there was a linear relationship ($r^2 = .99$) between overall group means and standard deviations, showing that the variance increased as a function of condition difficulty. We then plotted the condition means for the dyslexic group against those of the control group (Figure 2B). All data points were located above the diagonal, which reflects the consistently lower performance of dyslexics across all conditions (note that the diagonal represents identical performance for the two groups). As expected, the data points systematically departed from the diagonal as conditions became more difficult. Importantly, however, all points were located on a single regression line, which accounted for 99% of the variance.

Overall, the data clearly show that the difference in performance (and variability) between the two groups increased progressively as a function of condition difficulty. This analysis suggests that the deficit is identical across conditions and that a single global component (e.g. impairment of rapid access to phonological representations) is responsible for the differences between dyslexic and proficient readers across all conditions.

**Discussion**

In the present study, we tested one of the strong claims of the perceptual anchor theory, namely that deficits in RAN are due to the fact that the classic RAN task uses many repetitions of a small set of items. Hypothetically, dyslexic children show deficits in RAN because they fail to benefit from the repetitions to form a perceptual anchor. Thus, the anchoring theory predicted that with a large open set, the performance of dyslexics would not differ from that of controls (Ahissar, 2007). On the contrary, the present results revealed significant deficits in RAN when items were not repeated (large sets) both for numbers and objects. The size of the deficit was even bigger in the large-set condition than in the small-set condition, as indicated by significant interactions between set size and group. This pattern of results is clearly inconsistent with the strong claims of the perceptual anchor theory.

Similarly, in a re-analysis of some computerized RAN data, Ziegler (2008) investigated whether deficits in RAN were already present on the first naming trials of the RAN experiment. The anchor theory makes the strong prediction that no deficits should be present during the first trials of an experiment because time is
needed to set the anchor. In contrast to this prediction, Ziegler (2008) found that the RAN deficit was already present on the first trial of the experiment and its size remained stable across the entire experiment. In response to this argument, Ahissar and Oganian (2008) suggested that anchoring in Ziegler’s (2008) analysis must have emerged during the training trials because participants were familiarized with the names of the objects prior to the experiment (i.e. during training). Note, however, that repetition between training and test trials cannot explain the RAN deficits in the present large-set condition because, in the present study, a different set of objects and numbers was used for training and testing in the large-set condition. Together then, it is difficult to see how the perceptual anchor theory could explain the deficits observed in RAN.

To investigate whether a single global factor might explain the over-additivity between the effects of group and set size, we conducted supplementary analyses, as suggested by Faust et al. (1999). The results showed that the over-additivity was perfectly explained by a global underlying factor. Practically, this means that it does not matter whether small or large sets are used in RAN because both measure a single underlying process, that is, either a general impairment in processing speed or a more specific impairment in rapid access to phonological representations. A similar pattern has been found with regard to the over-additivity between the effects of lexicality and group (i.e. larger deficits for nonwords than for words). Again, the over-additivity was perfectly explained by a global underlying factor (Di Filippo, De Luca, Judica, Spinelli & Zoccolotti, 2006; Zoccolotti, De Luca, Judica & Spinelli, 2008).

The perceptual anchor theory makes an incorrect prediction not only for speeded naming tasks but also for speech perception tasks. The theory claims that impairments in speech perception tasks are found not because speech perception is impaired but because most speech perception tasks rely on a small set of repeated items (e.g. /ba/ versus /pa/) for which listeners have to respond to the same stimulus with the same tag. A failure to form a perceptual anchor would therefore deteriorate performance in such tasks. However, speech–perception in-noise deficits have been reported when a large set of 16 pseudowords was used (Ziegler, Pech-Georgel, George, Alario & Lorenzi, 2005). Importantly, in that study, the deficit was larger for voicing than for other phonetic features, which points to a specifically phonetic deficit (see also, Mody, Studdert-Kennedy & Brady, 1997). It is hard to see why a perceptual anchor deficit should affect voicing more than other phonetic features.

While the present work shows that some of the empirical foundations of the perceptual anchor theory need to be revised, there are also problems with the theory itself. Most importantly, it is not clear what is causing the anchor problem and why some psychophysical tasks that involve anchors do not show any anchoring deficits (e.g. Corriveau, Pasquini & Goswami, 2007; but see Ahissar & Oganian, 2008). In the absence of a clear mechanism, it is thus possible that anchor deficits are not the cause but the consequence of a more general underlying problem.

Rather than searching for yet another unitary explanation of dyslexia, such as a deficit in setting up a perceptual anchor, recent work suggested that much can be gained in understanding dyslexia by taking into account the heterogeneity of dyslexia both in terms of reading performance and the deficits in various reading components. Indeed, it has been shown that knowing the size of the deficits on the subcomponents of reading (letter processing, access to the orthographic and phonological lexicon, phoneme processing) on a participant-by-participant basis allows one to predict fairly well not only the global reading level of an individual child but also the specific deficits of each child in terms of nonword or irregular word reading (Ziegler et al., 2008). It is unclear how individual variation of a perceptual anchor deficit will lead to the dissociations between word and nonword reading reported in a number of studies (e.g. Griffiths & Snowling, 2002). In sum then, while the perceptual anchor theory provides an exciting new hypothesis about dyslexia, its empirical and theoretical limitations are too substantial for it to become a viable alternative to current theories of dyslexia.
Appendix

Individual subject data in rapid object and number naming (data are collapsed across small and large sets)

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