Mirror Reading:

A Review of The Literature

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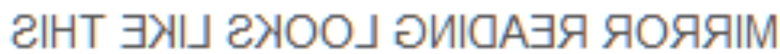
Introduction to Mirror Reading

Mirror Reading (MR) refers to the process of decoding letters and words presented in reverse-format.



There are numerous examples of uses of mirrored letters and symbols found in different linguistic portrayals around the world. Many languages, notably Arabic and English, include artistic depictions of characters and words in reverse format. Creating, decoding, and appreciating the meaning of such reversals, especially with efficiency, involves and array of complex cognitive capacities.

MR abilities and Mirror Effects (ME) are experiencing a modern surge of research attention, and are studied in specialized neuropsychological and educational labs around the world. MR paradigms are used to investigate questions on the brain circuitry of attention and memory, spatial transformation, skills transfer, and ability development in regular adult readers (e.g., Duñabeitia et al., 2011; Hilbert et al., 2014; Ilg et al., 2010, 2008; Jimura et al., 2014; Merbah et al., 2011). Historically, MR abilities have been studied as spontaneous remnants of brain injury, and regarded as symptoms of learning deficits in clinical samples - vestigial and spurious. Mirror reading has been investigated as problems in populations as diverse as Alzheimers's and Huntington's, Dyslexia and Parkinson's. However, new models of learning employ alternative lenses to medical models in understanding aptitudes. Recent depictions of MR describe the ability as a "prototypical skill" (Calabrese & Neugebauer, 2002, p. 225), signifying unique mental aptitudes. They suggest that procedural learning of MR result(s) from different, additive phenomena involving "visuo-spatial abilities, working memory capacity and the acquisition of new declarative visual memory contents" (p. 225).

Mirror Reading involves mental and physical skills different from those required to decode ordinary text. Expertise in reading mirrored text requires a concert of physical and cognitive abilities to harmonize in reverse. Fundamental eye movement patterns are interrupted, requiring right to left scanning (for English, and many other orthographies). Visual perception is inversed as mental rotation capacities spatially transform mirrored characters. To be MR proficient (such people do exist) means that one is able to rapidly deploy new mental templates to accurately represent backwards letter and word sequences in order to extract meaning. In effect, these 'specialists' possess the abilities to hold mirrored graphic icons in working memory and simultaneously manipulate them to accurately translate – them – and optimally retain them indefinitely.

**It bears noting that there is very little research on the degrees of patience and mental tolerance needed for (most) individuals to acquire basic proficiency of mirror reading speed/ accuracy/ integration/ retention (not "expertise").*

Mirror Reading In the Brain

A growing number of research teams around the world examine how practicing behavioural tasks, such as mirror reading, affects the functional neuroanatomy underlying the physical performance. New brain mapping technologies such as positron emission tomography (PET scan) and functional magnetic resonance imaging (fMRI) offer insights into the neuroplastic changes created by intentionally practicing different mirrored motor, visuomotor, perceptual and cognitive tasks, including mirror reading.

Mirror reading skills have been discussed in the research literature in relation to aptitude acquisition that follow that standard learning curve of as similar to other forms of focused

This indicates that reading mirrored script involves a late checking mechanism that is particularly important for reading a horizontally mirrored script. Together, our findings demonstrate that mirroring affects both early visual identification and later linguistic processes.

Indeed, adults reading mirrored text show a similar reading pattern as beginning or less-skilled readers.

the cognitive mechanisms underlying reading text with mirrored letters are still unknown, and it remains unclear which processes are affected by mirroring.

While reversed text may initially feel very demanding, the process of doing so becomes increasingly automatic with increasing training.

functional magnetic resonance imaging (fMRI) studies show structural changes in reading-related brain regions even after one training session (Poldrack et al., 1998). The learning curve follows a standard power function (Newell & Rosenbloom, 1993) indicating that letter identification becomes

Kolers and Perkins (1975) showed that readers were able to read horizontally mirrored text with near-normal speed after having read ca. 100 pages of mirrored text.

Rudiger Ilg's team (2008) identified regions of the brain that were unusually activated after mirror reading training over a span of weeks. Their data show that, when compared with regular reading, mirror reading training results in an activation of the dorsolateral occipital cortex, medial occipital cortex, superior parietal cortices, medial and dorsolateral prefrontal cortex, as well as anterior insula and cerebellum. Ilg et al., (2010) confirmed the shift of activation from right superior parietal to right dorsal occipital cortex and a corresponding increase of gray matter, in regions not usually associated with reading, but linked with visuo-spatial talents (Schmidtke et al., 1996) such as navigation and mental rotation, which are used in many daily living skills.

Goebel's (1998) functional imaging of mirror and inverse reading showed separate co-activated networks for activities related to oculomotion and spatial transformation. Researchers show that training in mirror reading involves physical brain changes notably in right hemisphere regions such as the superior parietal regions not usually associated with regular reading but with mental rotation and creative problem-solving. There is decreased activation in these brain areas suggesting that, with practice, mirror readings tasks require less mental exertion.

educed activation in the right involved in the mental transformations required for the task (Kassubek et al. 2001; Poldrack and Gabrieli 2001; Poldrack et al. 1998). These patterns of brain changes reveal important neuroplastic effects in key glion structures that occur as a result of reading reversed texts for merely a few minutes a day.

Poldrack (2001) showed that after five training sessions, compared with regular reading, MR was correlated with extensive activation in all four brain lobes.

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Mirror Reading and Working Memory

Working memory (WM) describes the cognitive element that allows one to actively maintain and manipulate information for higher order reasoning (Buschkuehl, Jaeggi, & Jonides, 2011; Jonides et al., 2008). Widely widely viewed as a core mental ability, working memory is fundamental to arrays of expertise in and outside of academic settings. WM capacity is fundamental to a general skills in acquiring knowledge and skills across contexts (Pickering, 2006), and is linked to the generalization of new learning to untrained tasks.

There is growing acknowledgement of the value of, and interest in, WM training in academic contexts. Around the world, educators strive to enhance WM capacities in their students to increase an array of related, and seemingly unrelated skills. Crone et al., (2006) conclude that WM training in children may allow typically developing children to get a head start in their WM abilities. WM training offers a relatively easy and straightforward means to "reduce the achievement gap" (Buschkuehl et al., 2011; Diamond & Lee, 2011). Scores on different measures of working memory are shown to increase with mirror reading practice (Beaton, 2004; Calabrese & Neugebauer, 2002). Researchers use various tools in their pursuit of working memory amplification, one of which includes mirrored stimuli (Raskin, 2011).

An emerging body of research evidence (e.g., Schmidtke et al., 1996; Calabrese & Neugebauer, 2002) demonstrates that activities that stimulate working memory skills, including those required for mirror reading, are associated with positive outcomes on activities that were not practiced. Hilbert (2014), who investigated the effects of MR training on decoding tests of different typographies, found that MR improvements generalize to untrained decoding tasks. Jimura (2014) investigated MR practice in association with cognitive task switching, concluding that MR involves distinct learning mechanisms that strengthen performance and executive control in later learning.

The research on mirror reading and memory is not completely congruous. According to Martone et al., (1984) patients with Huntington's disease display impairments in the acquisition of mirror reading skills. Schmidtke et al., (1998) found normal learning curves in these patients. Alzheimer's patients showed normal learning curves (e.g., Deewar, Pillon, & Dubois, 1993), whereas studies of mirror reading in patients with Parkinson's disease have found mixed results related to the acquisition and retention of mirror reading skills (Martone et al., 1984; Koenig, Thomas-Anterion & Lamong, 1999; Bondi & Kaszniak, 1991).

Conclusion

Data on the different effects of mirror reading training is of value to specialists in fields as diverse as educational psychology, occupational therapy, geriatric neurology, and cognitive psychopathology, as well as to professionals in areas of applied learning in industry - outside academic communities. Much more research is needed, especially on the precise brain structures and functions involved in mirror reading skills development in clinical and non-clinical populations of different ages and linguistic backgrounds.

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