

Designação do projeto: Reconhecimento visual da palavra e processamento ortográfico: Investigação e contributos da Psicologia Cognitiva, Neurociências, e Simulação Computacional

Código do projeto: LISBOA-01-0145-FEDER-028184 | PTDC/PSI-GER/28184/2017

Objetivo principal: OT 1 - Reforçar a investigação, o desenvolvimento tecnológico e a inovação

Região de intervenção: Lisboa

Entidades beneficiárias: Faculdade de Psicologia da Universidade de Lisboa (Proponente);
FCiências.ID - Associação para a Investigação e Desenvolvimento de Ciências (Parceiro)

Data de aprovação: 03-03-2018

Data de início: 14-06-2018

Data de conclusão: 13-06-2022

Custo total elegível – FP-ULisboa: 164.089,68 Euros

Apoio financeiro da União Europeia – FP-ULisboa:

FEDER (40%) – 65.635,87 Euros

FCT (Orçamento de Estado 60%) – 98.453,81 Euros

O presente projeto tem um orçamento total elegível de 183.589,38€, sendo co-financiado pelo FEDER (Lisboa 2020) no valor de 73.435,75€ e pelo Orçamento de Estado em 110.153,63€.

Objetivos, atividades e resultados esperados:

Para criar uma conta de e-mail temos de passar num teste de reconhecimento de palavras com letras distorcidas: fácil para humanos, difícil para agentes artificiais. Este CAPTCHA (Completely Automated Public Turing test to tell Computers and Humans Apart) mostra quão pouco sabemos sobre o processamento ortográfico, i.e, o acesso à identidade abstrata das letras: de pixéis até palavras.

Investigação, incluindo a nossa, mostrou que a leitura é ultra exigente sobre o processamento visual e é suportada pela via occipitotemporal ventral (vOT) por reciclagem parcial do reconhecimento de objetos, a função original da vOT. Assim, o código ortográfico ou é distinto de outras representações visuais ou é reconhecimento visual modelado pela linguagem. Como podemos testá-lo, se muitas propriedades da vOT são ideais para a leitura que, por sua vez, depende do mapeamento entre ortografia e fonologia, num sistema interativo?

A ideia inovadora é que podemos pela investigação de duas adaptações visuais necessárias à leitura, mas que colidem com propriedades originais do reconhecimento de objetos: reduzida integração espacial de traços em letras, i.e., crowding reduzido, e discriminação de imagens em espelho (d - b).

VOrtEx responde a 3 questões: A que nível de processamento ocorrem estas adaptações no leitor adulto? Com que trajetória de desenvolvimento? Estão corrompidas na perturbação de leitura? Desenhos cognitivos exímios de reconhecimento de letras e palavras, EEG de alta resolução temporal (Potenciais Relacionados com Eventos, ERP, e Potenciais visuais evocados de estado, SSVEP), e aprendizagem automática são impulsionados pela nossa competência científica e dos consultores, os recursos do centro I&D, estudantes de mestrado e doutoramento e o investigador doutorado a contratar (FTE). Para um cenário pleno, testaremos adultos (Estudo1), iletrados, ex-iletrados e letrados, crianças do 1º-6º ano (Estudo2), e disléxicos (Estudo3). Prevemos que estas adaptações ocorrem numa fase precoce do processamento em adultos, alcançam a plenitude após poucos anos de experiência de leitura, mas são deficitárias na dislexia. A natureza teórica da Psicologia Cognitiva, Neurociência e Ciência Computacional e a abordagem inovadora multi-método são chave para o sucesso; ciência fundamental e translacional além-fronteiras.

VOrtEx responde a desafios de Saúde, Sociedades Inclusivas e Seguras com planos de disseminação na linha do Portugal2020: "se o desenvolvimento inteligente é sobre conhecimento e inovação, investimento nas competências de literacia é um pré-requisito para o seu alcance" (p.11).

Major achievements, deliveries, and outputs

AIM: To unravel the nature of orthographic representations: from pixels into words.

HOW? By investigating two visual adaptations required for reading which depart from object recognition (the original function of the ventral stream): reduced crowding and mirror-image discrimination.

GOALS: To determine when in processing these adaptations occur in adult readers; To trace their developmental curve; To examine if they crash in the reading disorder.

STUDIES: Skillful cognitive designs on letter and word recognition, electrophysiological data, and machine learning techniques. Deep learning networks will emulate these adaptations in the adult system (Study1). Studies test adult readers (Study1), illiterate, ex-illiterate and literate adults, 1st-6th-graders (Study2), dyslexic readers (Study3).

FINDINGS: These adaptations occur early at prelexical stages of orthographic processing, not tainted by high-level influences in the mature reading system, although they do show a wide developmental trajectory, being fully automatized only at 5-6th grade, and show a pattern of deviance in developmental dyslexia, even in adult readers.

TRANSLATIONAL OUTPUT: Health, and Inclusive Societies along Portugal2020.

Scientific Publications | Publicações científicas

Books or book chapters | Livros ou capítulos de livros

Leite, I., & Fernandes, T. (2019). A Dark Consequence of Developmental Dyslexia: Discrimination of Mirror Images is not Automatized. *In* E. Witruk & D. S. Utami (Eds.), *Traumatic Experiences and Dyslexia* (pp. 215-226). Peter Lang. <https://doi.org/10.3726/b15891>

Book chapter published by international editor regarding Study 3, relative to the deficit in automatic processing of mirror images by dyslexic readers and its comparison with efficient processing by typically-developing control readers. Publication under scientific domain framed by RIS3.

Scientific papers in international journals | Artigos em revistas internacionais

Araujo, S., Fernandes, T., & Huettig, F. (2019). Learning to read facilitates the retrieval of phonological representations in rapid automatized naming: Evidence from unschooled illiterate, ex-illiterate, and schooled literate adults. *Developmental Science*, 22(4), e12783. <https://doi.org/10.1111/desc.12783>

Paper about Study 2, regarding the impact of literacy acquisition and the emergence of orthographic representations in naming of visual objects. Behavioral study conducted with illiterate adults, and ex-illiterate and schooled literate adults from the same socioeconomic and cultural background of the former group.

Publication under scientific domain framed by RIS3.

Araújo, S., Maurer, U., & Fernandes, T. (2022). Editorial: Multisensory integration as a pathway to neural specialization for print in typical and dyslexic readers across writing systems [Editorial]. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.992380>

Paper resulting from the joint organization of the PI and Co-PI of the project with Urs Maurer from The Chinese University of Hong Kong, China, of a special issue in Frontiers in Psychology framed by Study 3 on the differences in neural and cognitive expression of reading in dyslexic and typical populations.

Araújo, S., Domingues, M., & Fernandes, T. (2022). From Hand to Eye: a Meta-Analysis of the Benefit from Handwriting Training in Visual Graph Recognition. *Educational Psychology Review*, 34(3), 1577-1612. <https://doi.org/10.1007/s10648-021-09651-4>

Meta-analysis conducted in **Study 2**, regarding how mirror-image discrimination, which is a necessary adaptation for learning to read and becoming a fluent reader is assisted by handwriting practice. We showed that the benefit from HW training was moderate-to-large and significant (Hedge's $g = 0.58$, $SE = .09$) and was also modulated by the type of control training (larger relative to motor, than to visual control, , phonological training (larger when it was absent than present), and granularity of visual discrimination (larger for fine-grained, including mirror-image differences, than coarse-grained).

Publication under scientific domain framed by RIS3.

Fernandes, T., Xavier, E., Domingues, M., & Araújo, S. (2022). Where is mirror invariance? Masked priming effects by mirrored and rotated transformations of reversible and nonreversible letters. *Journal of Memory and Language*.

<https://doi.org/10.1016/j.jml.2022.104375>

Paper presenting the core findings of **Study 1**, relative to the behavioral and electrophysiological expression of mirror-image discrimination of letters, which happens in adult fluent readers automatically since an early stage of prelexical orthographic processing. These findings were demonstrated while adopting several different tasks and procedures with letter strings and single letters. This pattern of results was also investigated with null-hypothesis significance testing methods as well as with Bayesian statistics demonstrating their robustness.

Fernandes, T., & Araújo, S. (2021). From Hand to Eye With the Devil In-Between: Which Cognitive Mechanisms Underpin the Benefit From Handwriting Training When Learning Visual Graphs? [Hypothesis and Theory]. *Frontiers in Psychology*, 12, 736507.

<https://doi.org/10.3389/fpsyg.2021.736507>

Theoretical paper about **Study 2**, regarding how mirror-image discrimination, which is a necessary adaptation for learning to read, which disappears for orthographic processing along reading development is assisted by handwriting practice. In this paper we propose a theoretical framework to systematically test this hypothesis and discuss the two conflicting theoretical proposals that have been proposed.

Publication under scientific domain framed by RIS3.

Fernandes, T., Arunkumar, M., & Huettig, F. (2021). The role of the written script in shaping mirror-image discrimination: Evidence from illiterate, Tamil literate, and Tamil-Latin-alphabet bi-literate adults. *Cognition*, 206, 104493. <https://doi.org/10.1016/j.cognition.2020.104493>

Empirical paper regarding **Study 2**, and the behavioral results in the same-different matching tasks, investigating mirror-image discrimination and its relationship with the properties of the written system (i.e., having or not having mirrored letters: latin alphabet vs. tamil aksharas, respectively) by testing illiterate adults (non-readers), and two groups of readers, i.e., monoliterate in Tamil and biliterate in Tamil and Latin alphabet.

Publication under scientific domain framed by RIS3.

Vágvölgyi, R., Bergström, K., Bulajić, A., Klatte, M., **Fernandes, T.**, Grosche, M., Huettig, F., Rüsseler, J., & Lachmann, T. (2021). Functional illiteracy and developmental dyslexia: looking for common roots. A systematic review. *Journal of Cultural Cognitive Science*, 5(2), 159-179.

<https://doi.org/10.1007/s41809-021-00074-9>

Paper relative to **Study 3**, regarding the differences in visual processing found in dyslexic readers relative to control readers and found in illiterate adults relative to literate participants. This theoretical paper is the output of a joint initiative including the PI of the project and international researchers from Kaiserslautern University and the Max Plank Institute for Psycholinguistics.

Publication under scientific domain framed by RIS3.

Ventura, P., Leite, I., & Fernandes, T. (2018). The development of holistic face processing: An evaluation with the complete design of the composite task. *Acta Psychologica*, 191, 32-41.

<https://doi.org/10.1016/j.actpsy.2018.08.015>

Paper relative to **Study 2**, regarding the development of visual processing strategies of visual face recognition associated with reading acquisition and development, from pre-readers, 4-year-olds to children at the end of the primary school (9-year-olds at the 4th-grade).

Ventura, P., Fernandes, T., Leite, I., Pereira, A., & Wong, A. C.-N. (2019). Is holistic processing of written words modulated by phonology? *Acta Psychologica*, 201, 102944.

<https://doi.org/10.1016/j.actpsy.2019.102944>

Paper about Study 1, regarding the nature of lexical orthographic representations available in the mature reading system and whether top-down effects could explain the behavioral trademarks of reading expertise, that is, the holistic processing of written words.

Ventura, P., Fernandes, T., Pereira, A., Guerreiro, J. C., Farinha-Fernandes, A., Delgado, J., Ferreira, M. F., Faustino, B., Raposo, I., & Wong, A. C. N. (2020). Holistic word processing is correlated with efficiency in visual word recognition. *Attention, Perception, & Psychophysics*, 82(5), 2739-2750. <https://doi.org/10.3758/s13414-020-01988-2>

Paper about Study 1, regarding the nature of lexical orthographic representations available in the mature reading system and whether these representations were associated with reading proficiency as expressed by the word-frequency effect (i.e., faster recognition of high- than low-frequency words) computed in an independent lexical decision task as a proxy of fast access to lexical orthographic representations.

Fernandes, T., Velasco, S., & Leite, I. (submitted). Letters into the looking glass along reading development: Developmental trajectory of mirrored and rotated letter processing within words. *Reading Research Quarterly*.

Paper presenting the major findings on Study 2, regarding the developmental trajectory of automatic mirror-image discrimination of letters within words in readers from 2nd-6th grade and its relationship with reading abilities. This paper was also part of a master thesis and was recently submitted to a top journal.

Fottner, N., Fernandes, T., & Correia, L. (in preparation). Assessing the emergence of letter detectors in Deep Neural Networks.

Paper presenting the major findings on the computational word conducted in Study 1 with deep belief networks. The illiterate network models the probability distribution underlying images from natural and urban scenes modelling the causal structure and the domain-general features which compose these images. Upon the learned connectivity, the model then uses the same domain-general features from natural scenes to now model the probability distribution underlying geometrical shapes. Next, the model uses the learned representation about geometrical features to learn to classify different geometrical shapes based on their identity. The implemented DBN illiterate model is composed of 4 layers; the input layer, the second and third being Restricted Boltzmann Machines (RBM), and the output layer being defined as a linear classifier.

Communications in scientific events| Comunicações em encontros científicos

Communications at international conferences| Comunicações em encontros científicos internacionais

Araújo, S. (2021). The role of handwriting learning experience in the ability to discriminate letters. **IV Workshop of Society for Cognitive Science of Culture.** Kaiserslautern, Germany. *Communication presented at meeting organized by the Society for Cognitive Science of Culture (SCSC) relative to Study 2, regarding our meta-analysis about the role of handwriting practice and other moderator factors in mirror-image discrimination of letters and subsequent visual symbol recognition (published in Educational Psychology Review).*

Araújo, S., Bramão, I., Dias, D., & Fernandes, T. (2022). Are adult dyslexic readers lost in the forest? Processing of hierarchical stimuli by typical and dyslexic readers. **Joint international meeting by APPE and SEPEX.** Faro, Portugal.

Poster presented at international conference jointly organized by the Spanish Society for Experimental Psychology (SEPEX) and the Portuguese Association of Experimental Psychology (APPE). Work about **Study 3**, regarding deficient letter processing in crowded conditions by dyslexic adults.

Araújo, S., Faísca, L., Reis, A., & Inácio, F. (2022). Phonological information can modulate orthographic processing already at the earliest stages of visual processing: an electrophysiological study. **International Conference of Cognitive Neuroscience, ICON 2022.** Espoo, Finland.

Poster presented at international meeting relative to **Study 1**, regarding the electrophysiological findings of reduced crowding in fluent adult readers and the earliest interactive impact of phonology in letter processing.

Catronas, D., Reis, A., Faísca, L., **Fernandes, T., & Araujo, S. (2019).** Does training in handwriting facilitate visual letter recognition? Evidence from eye-movements. **Third IWORDD, 2019 - International Workshop on Reading and Developmental Dyslexia.** San Sebastian, Spain.

Communication presented at international conference organized by the IWORDD (International Workshop on Reading and Developmental Dyslexia) relative to **Study 2**, regarding the emergence of orthographic representations and abstract letter identities that are sensitive to mirror-image differences in typically-developing readers. This study was part of a master thesis by D. Catronas supervised by the Co-PI of the project (S. Araujo).

Corbal, M. L., **Fernandes, T., & Araujo, S. (2018).** Do motor representations assist mirror-image discrimination? Evidence on preliterate children playing tablet games. **I Workshop on Cognitive Science of Culture,** Lisbon, Portugal.

Communication presented at founding meeting of the Society for Cognitive Science of Culture (SCSC) relative to **Study 2**, regarding the emergence of orthographic representations and abstract letter identities that are sensitive to mirror-image differences in preliterate children learning letters via handwriting.

Fernandes, T., & Kolinsky, R. (2019). Learning to read enhances the Ebbinghaus illusion. **Third Biennial International Convention of Psychological Science, ICPS,** Paris, France.

Communication presented at international conference organized by the Association for Psychological Science (APS). Paper about **Study 2**, regarding the impact of literacy acquisition on a reduced crowding effect found in ex-illiterate and schooled literate adults, but not in illiterate adults from the same socioeconomic and cultural backgrounds.

Fernandes, T. (2021). Reading glasses on the Ebbinghaus illusion. **IV Workshop of Society for Cognitive Science of Culture.** Kaiserslautern, Germany.

Oral communication presented at international conference organized by the Society for Cognitive Science of Culture (SCSC). Paper about **Study 2A**, regarding the impact of literacy acquisition on a reduced crowding effect found both in adult and child populations who are readers.

Fernandes, T., Lourenço, A., Aguilar, M., & Domingues, M. (2022). When in orthographic processing does the vertex effect occur? **22nd conference of the ESCOP (European Society for Cognitive Psychology).** Lille, France.

Poster presented at international conference of the European Society for Cognitive Psychology on the temporal course of the vertex effect investigated with fluent readers in **Study 1**.

Fernandes, T., Xavier, E., & Araújo, S. (2022). Fernandes, T., Xavier, E., & Araújo, S. (2022). Masked priming effects by mirrored and rotated transformations of reversible and nonreversible letters **V Workshop of Society for Cognitive Science of Culture.** Madrid, Spain.

Oral communication presented at international conference organized by the Society for Cognitive Science of Culture (SCSC). Paper about **Study 1**, recently published in *Journal of Memory and Language*.

Fottner, N., **Correia, L., & Fernandes, T. (2022)**. Modelling early visual processes of illiterates with Deep Belief Networks to further assess the emergence of the letter specialized system.

Joint international meeting by APPE and SEPEX. Faro, Portugal.

*Poster presented at international conference jointly organized by the Spanish Society for Experimental Psychology (SEPEX) and the Portuguese Association of Experimental Psychology (APPE). Computational simulation work about **Study 1**, regarding the performance of deep learning networks on visual processing, letter identification, and reduced crowding.*

Reis, A., **Araújo, S.**, Salomé, I. & Faisca, L. (2019). Dyslexia in adulthood in different orthographic systems: A review and meta-analysis. **Third IWORDD 2019 – International Workshop on Reading and Developmental Dyslexia**. San Sebastian, Spain.

*Communication presented at international conference organized by the IWORDD (International Workshop on Reading and Developmental Dyslexia) relative to **Study 3**, regarding a potential deficit on automatic mirror-image discrimination by dyslexic adults during visual word recognition.*

Vágvölgyi, R., Bergström, K., Bulajić, A., Klatte, M., **Fernandes, T.**, Grosche, M., Huettig, F., Ruseler, J., & Lachmann, T. (2021). Functional illiteracy and developmental dyslexia: Looking for common roots. Society for the Scientific Studies of Reading, Conference 2021.

*Poster presented at international conference organized by the Society for the Scientific Studies of Reading relative to a joint action by the PI of this project and researchers from Kaiserslautern University, and from the Max Plank Institute for Psycholinguistics framed by **Study 3**, regarding the differences in visual processing found in dyslexic readers relative to control readers and found in illiterate adults relative to literate participants. Part of this study was published in Journal of Cultural Cognitive Science.*

Communications by invitation (international)

Keynote speaker in international conference: **Fernandes, T. (2018)**. Cognitive Science of Culture – literacy: an acculturation of the brain and mind. Opening talk. **I Workshop of the Society for Cognitive Science of Culture**. Lisbon, Portugal.

Invited communication: **Fernandes, T. (2019)**. The visual facet of learning to read: Consequences on visual processing of letters and non-letters. **CONNEX seminary, Center for Research in Cognition & Neurosciences**, Université Libre de Bruxelles, Belgium.

Keynote speaker in international conference: **Fernandes, T. (2020)**. Literacy in a Multilingual World: Mirror-image discrimination is about explicit training in the script. **III Annual Meeting of the Society for the Cognitive Science of Culture**. Goa, India

Invited communication: **Fernandes, T. (2021)**. The letter in the mirror: consequences of learning to read in mirror-image processing. **Donders Session “Cultural Brain”**. Donders Institute for Brain, Cognition, and Behavior, Radboud University, Nijmegen, Netherlands.

Invited (national) communication: **Fernandes, T. (2020)**. The impact of learning to read in visual object recognition and orientation processing. **VisLab – Computer and Robot Vision Laboratory**. Instituto Superior Técnico (TÉCNICO | LISBOA), Lisboa, Portugal.

Communications at national events | Comunicações em encontros científicos nacionais

Corbal, M. L., **Fernandes, T., & Araujo, S. (2019)**. Long live handwriting! The benefits of handwriting on visual recognition of symbols. **XIV Meeting of the Portuguese Association of Experimental Psychology (APPE)**, Faro, Portugal.

Communication presented at national conference organized by the Portuguese Association of Experimental Psychology. Paper about **Study 2**, regarding the emergence of orthographic representations and abstract letter identities that are sensitive to mirror-image differences, considering whether handwriting practice assists on this visual adaptation necessary for literacy acquisition.

Díaz-Lago, M., Araújo, S., & Fernandes, T. (2020). Is a mirrored letter a stronger prime than a rotated letter? Evidence from a behavioural sandwich priming study. **XIV Meeting of the Portuguese Association of Experimental Psychology (APPE)**, Faro, Portugal.

Poster presented at national conference organized by the Portuguese Association of Experimental Psychology, regarding **Study 1**, relative to the electrophysiological expression and temporal course mirror-image discrimination of letters, which happens in adult fluent readers automatically since an early stage of prelexical orthographic processing.

Domingues, D., Kolinsky, R., Fernandes, T. (2021). Beginning readers show stronger Ebbinghaus illusion than preliterate children. **XV Meeting of the Portuguese Association of Experimental Psychology (APPE)**, Lisboa, Portugal.

Poster presented at national conference organized by the Portuguese Association of Experimental Psychology, regarding **Study 2**, and specifically, the impact of literacy acquisition on a reduced crowding effect found in first-grade readers but not in preliterate children, matched in age and cognitive development and differing only on schooling/literacy. This poster was part of a master thesis.

Fernandes, T. & Kolinsky, R. (2019). Learning to read shapes the susceptibility to the Ebbinghaus illusion. **XIV National Meeting of Associação Portuguesa de Psicologia Experimental (Portuguese Association of Experimental Psychology)**, Universidade de Évora, Évora, Portugal.

Communication presented at national conference organized by the Portuguese Association of Experimental Psychology. Paper about **Study 2A**, regarding a specific visual adaptation promoted by literacy: a reduced crowding effect, which was found in ex-illiterate and schooled literate adults, but not in illiterate adults from the same socioeconomic and cultural backgrounds.

Fernandes, T. (2021). Tamil readers can discriminate mirror images. **XV National Meeting of Associação Portuguesa de Psicologia Experimental, APPE, (Portuguese Association of Experimental Psychology)**. ISPA, Lisboa, Portugal.

Communication presented at national conference organized by the Portuguese Association of Experimental Psychology. Paper about **Study 2B**, regarding the impact of literacy acquisition on mirror-image discrimination, considering the influence of learning to read disentangled from the properties of the script, related with the article published in *Cognition* 2021.

Lourenço, A., **Aguilar, M., & Fernandes, T. (2022).** Visual words live on the edge: the impact of vertices in lexical access. **XVI Meeting of the Portuguese Association of Experimental Psychology (APPE)**. Faro, Portugal.

Poster presented at national conference organized by the Portuguese Association of Experimental Psychology (APPE). Work about **Study 1**, regarding the behavioral results found in Study 1A with fluent adult readers. This work was also part of a master thesis.

Pascual, M. Stolinska, J., Esteves, S., Bramão, I., **Araújo, S., & Fernandes, T. (2022).** A possible association between global processing of 3D objects and visual word recognition. **XVI Meeting of the Portuguese Association of Experimental Psychology (APPE)**. Faro, Portugal.

Poster presented at national conference organized by the Portuguese Association of Experimental Psychology (APPE). Work about **Study 3**, regarding the behavioral results found between reading performance (in dyslexic and control readers) and visual processing of nonlinguistic material.

Velasco, S. & Fernandes, T. (2022). Developmental trajectory of mirrored letter processing within words. **XVI Meeting of the Portuguese Association of Experimental Psychology (APPE)**. Faro, Portugal.

Poster presented at national conference organized by the Portuguese Association of Experimental Psychology (APPE). Work about **Study 2**, regarding the developmental changes in automatic mirror-image discrimination along reading acquisition and development from 2nd- to 6th- grade and relative to adults.

Organization of Scientific events | Organização de seminários e conferências

I Workshop of the Society for Cognitive Science of Culture, Faculdade de Psicologia, Universidade de Lisboa, Portugal (June, 2018).

Scientific event organized by the PI and Co-PI of the project with the consultants and international researchers and partners investigating the changes and development of visual adaptations on perceptual processing, promoted by learning to read. Founding meeting of the **Society for Cognitive Science of Culture**

(<https://culturalcogsci.org/index.html>) with international publication by Springer, i.e., *Journal of Cultural Cognitive Science* (<https://www.springer.com/journal/41809>).

VOrtEx week, colloquium. Ciclo de conferências. Faculdade de Psicologia, Universidade de Lisboa, Portugal (May, 2022).

Scientific colloquium with two seminars by the consultants of the project José Morais and Régine Kolinsky, Université Libre de Bruxelles, Belgium, organized by the PI and Co-PI of the project, for the academic public, including researchers, students (undergraduate and graduate), and scientific staff of Universidade de Lisboa.

Morais, J. (12 May 2022). "A key concept shared by psychology, science, and philosophy"

After a very short and contextualized self-introduction, and having evoked both the rapid and important evolution of the sciences of cognition and some of the corresponding major concepts, I will confront the Information-Processing Perspective with the Cultural-Historical-Activity-Theory (CHAT) and will consider the involvement of philosophy in the scientific development. Then, I will argue for a double necessity: of coupling psychology and philosophy in the joint study of cognition and culture, and of taking the concept of activity, or agency, as crucial to both. This will require an almost permanent recall of the work of historical theoreticians.

Kolinsky, R. (17 May 2022). "Literacy in a post-truth world"

As literacy is a "mindtool" that facilitates access to information and the acquisition of new knowledge, it impacts many perceptual and cognitive abilities, including knowledge and precision of semantic concepts, syntactic processing, verbal memory, executive functions and logical thinking. This raises the question of whether literacy also contributes to increasing the quality and depth of critical thinking and thus would help decreasing vulnerability to misinformation. We will present preliminary data on adults and adolescents with quite different levels of literacy. In addition to the peculiarities of the reading profile of participants with low literacy levels, we will discuss their over-gullibility to information, including disinformation such as that presented by conspiracy theories. We will also discuss the various ways critical thinking might be improved and present preliminary data of an intervention study aiming at boosting this capacity.

Organization of Special Issue in International Scientific Journal | Organização de número especial em revista científica internacional

Coordination of Research Topic in *Frontiers in Psychology* with Susana Araújo (Co-PI of this project) and Urs Maurer (The Chinese University of Hong Kong, China).

Multisensory Integration as a Pathway to Neural Specialization for Print in Typical And Dyslexic Readers Across Writing Systems. <https://www.frontiersin.org/research->

[topics/18678/multisensory-integration-as-a-pathway-to-neural-specialization-for-print-in-typical-and-dyslexic-readers#articles](https://doi.org/10.3389/fpsyg.2022.992380)

Araújo, S., Maurer, U., & Fernandes, T. (2022). Editorial: Multisensory integration as a pathway to neural specialization for print in typical and dyslexic readers across writing systems [Editorial]. *Frontiers in Psychology*, *13*. <https://doi.org/10.3389/fpsyg.2022.992380>

Relatórios | Reports

Progress reports presented to Faculdade de Psicologia and Faculdade de Ciências, ULisboa.

Fernandes, T. (2019). First-year progress report, project PTDC/PSI-GER/28184/2017, LISBOA-01-0145-FEDER-028184.

Fernandes, T. (2020). Second-year progress report, project PTDC/PSI-GER/28184/2017, LISBOA-01-0145-FEDER-028184.

Fernandes, T. (2021). Third-year progress report, project PTDC/PSI-GER/28184/2017, LISBOA-01-0145-FEDER-028184.

Fernandes, T. (2022). Final report, project PTDC/PSI-GER/28184/2017, LISBOA-01-0145-FEDER-028184.

Fernandes, T. (2021). *Final report* under the Programme *Verão com Ciência 2021* in the context of R&D lines/projects at the Research Center in Psychological Science, CICPSI, funded by FCT/MCTES through national funds (PIDDAC).

Research fellowship report by the students with the starting grant under the programme Verão com Ciência 2021.

A. Lourenço (2021). The role of motor features (strokes) in letter recognition by fluent readers Report under *Verão com Ciência 2021*, FCT, starting Grant for 1 month (september 2021). Faculdade de Psicologia, Universidade de Lisboa (supervision: **T. Fernandes**).

S. Velasco (2021). Locus of mirror discrimination in orthographic processing. Report under *Verão com Ciência 2021*, FCT, starting Grant for 1 month (september 2021). Faculdade de Psicologia, Universidade de Lisboa (supervision: **T. Fernandes**).

Research fellowship activities report by the research assistants (BI of the project).

Domingues, M. (2020). Research report of the activities conducted under the research grant in Psychology (master degree). Research fellowship supervisor: **T. Fernandes**.

Fottner, N. (2022). Research report of the activities conducted under the research grant in Computational science (bachelor degree). Research fellowship supervisor: **L. Correia**.

Reports of the Internship in Experimental and Clinical Neuropsychology by master students

M. Domingues (2019). Internship report in Cognitive Neuropsychology. Master in Psychology: Social Cognition, Faculdade de Psicologia, Universidade de Lisboa. Supervision by **T. Fernandes**.

M. Granadeiro (2019). Internship report in Cognitive Neuropsychology. Master in Psychology: Social Cognition, Faculdade de Psicologia, Universidade de Lisboa. Supervision by **T. Fernandes** and co-supervision by **I. P. Martins**, Faculdade de Medicina de Lisboa, Hospital de Santa Maria, Lisboa.

D. Dias (2021). Internship report in Cognitive Neuropsychology. Master in Psychology: Social Cognition, Faculdade de Psicologia, Universidade de Lisboa. Supervision by **T. Fernandes** and co-supervision by **I. P. Martins**, Faculdade de Medicina de Lisboa, Hospital de Santa Maria, Lisboa.

S. Velasco (2022). Internship report in Cognitive Neuropsychology. Master in Cognitive and Social Psychology. Faculdade de Psicologia, Universidade de Lisboa. Supervision by **T. Fernandes**.

Advanced Training | Formação Avançada

Master thesis

E. Xavier (2018). From pixels to letters: Discrimination of orientation contrasts during visual word recognition. Master thesis in Psychology – Social Cognition, Faculdade de Psicologia, Universidade de Lisboa (Supervisor: **T. Fernandes**).

*Master thesis supervised by T. Fernandes regarding the behavioral and electrophysiological studies in fluent adult readers that were part of **Study 1**, relative to the mirror-image discrimination of letters that happens in adult readers automatically since an early stage of prelexical orthographic processing.*

M. Domingues (2019). The impact of learning to read in the susceptibility to a visual illusion of size. Master Thesis in Psychology – Social Cognition. Faculdade de Psicologia, Universidade de Lisboa (Supervisor: **T. Fernandes**).

*Master thesis supervised by T. Fernandes which was part of **Study 2**, regarding the reduction of the crowding effect promoted by learning to read, as assessed by the magnitude of the Ebbinghaus illusion. This study was conducted with three groups of adults differing only by literacy/schooling (illiterate, ex-illiterate, and schooled literate) and two groups of children matched in age and cognitive development but differing on literacy/schooling (preschool prereaders and first-grade readers).*

D. Catronas (2020). The influence of sensorimotor training in learning a novel script: A comparison between handwriting and visual learning. Master Thesis in Neurosciences (Neuropsychology), Universidade do Algarve (Supervisors: **S. Araújo** & L. Faísca).

*Master thesis supervised by S. Araújo (Co-PI of the project), part of **Study 2**, regarding the influence of handwriting practice in mirror-image discrimination during letter recognition.*

A. Lourenço (2022). Visual words live on the edge: Behavioral effects of vertex deletion. Master Thesis in Cognitive and Social Psychology. Faculdade de Psicologia, Universidade de Lisboa. (Supervision: **T. Fernandes**).

*Master thesis supervised by T. Fernandes regarding the early stages of orthographic processing and the degree of similarity between the computations involved in visual words and objects, as investigated in **Study 1**.*

S. Velasco (2022). The developmental trajectory of mirrored and rotated letter processing within words. Master Thesis in Cognitive and Social Psychology. Faculdade de Psicologia, Universidade de Lisboa. (Supervision: **T. Fernandes**).

*Master thesis supervised by T. Fernandes regarding the developmental course of automatic mirror-image discrimination of letters within words, from the 2nd- to the 6th-grade and its relationship with reading abilities, as investigated in **Study 2**.*

N. Fottner (2022). Assessing the emergence of letter detectors in Deep Generative Networks. Master in Cognitive Science. Universidade de Lisboa. (Supervision: **T. Fernandes & L. Correia**)
Master thesis supervised by T. Fernandes and L. Correia on the computational modeling with deep learning networks of letter identification and the visual adaptations promoted by literacy (simulated as identification of letters within words), part of **Study 1**.

J. Stolinska (2022). Behavioral markers and neural correlates of visuospatial processing in individuals with dyslexia. Master in Cognitive Science. Universidade de Lisboa. (Supervision: **T. Fernandes & S. Araújo**).

Master thesis supervised by T. Fernandes and S. Araújo (PI and Co-PI of this project) on **Study 3**, regarding the electrophysiological and behavioral data of deviant reduced crowding in dyslexic readers during letter processing.

Internship in Experimental and Clinical Neuropsychology by master students

M. Domingues (2019). Internship in Cognitive Neuropsychology. Master in Psychology: Social Cognition, Faculdade de Psicologia, Universidade de Lisboa. Supervision by **T. Fernandes**.

M. Granadeiro (2019). Internship in Cognitive Neuropsychology. Master in Psychology: Social Cognition, Faculdade de Psicologia, Universidade de Lisboa. Supervision by **T. Fernandes** and co-supervision by **I. P. Martins**, Faculdade de Medicina de Lisboa, Hospital de Santa Maria, Lisboa.

D. Dias (2021). Internship in Cognitive Neuropsychology. Master in Psychology: Social Cognition, Faculdade de Psicologia, Universidade de Lisboa. Supervision by **T. Fernandes** and co-supervision by **I. P. Martins**, Faculdade de Medicina de Lisboa, Hospital de Santa Maria, Lisboa.

S. Velasco (2022). Internship in Cognitive Neuropsychology. Master in Cognitive and Social Psychology. Faculdade de Psicologia, Universidade de Lisboa. Supervision by **T. Fernandes**.

ERASMUS+ Internship

V. Jahn (2020). A developmental investigation about the underlying neuronal mechanisms of visual word processing by examining the phenomena of the brain's ability to discriminate between mirror image in parallel with reading acquisition. Report under ERASMUS+ internship, Faculdade de Psicologia, Universidade de Lisboa (supervision: **T. Fernandes**).

Internship (1 month) under Verão com Ciencia 2021, FCT

A. Lourenço (2021). The role of motor features (strokes) in letter recognition by fluent readers. Report under Verão com Ciencia 2021, FCT, starting Grant for 1 month (september 2021). Faculdade de Psicologia, Universidade de Lisboa (supervision: **T. Fernandes**).

S. Velasco (2021). Locus of mirror discrimination in orthographic processing. Report under Verão com Ciencia 2021, FCT, starting Grant for 1 month (september 2021). Faculdade de Psicologia, Universidade de Lisboa (supervision: **T. Fernandes**).

Integration of knowledge in activities of higher education | Integração do conhecimento em atividades de formação superior

Academic year 2018-2019

Fernandes, T. (2018). Course “Cognitive Neuroscience of Reading” (1st semester, master in Psychology: Social Cognition). Class on the visual adaptations necessary for learning to read (October, 2018),

Araújo, S. (2018). Developmental dyslexia and deficient letter processing (1st semester, master in Psychology: Social Cognition). Class on the visual adaptations necessary for learning to read (December, 2018),

Fernandes, T. (2019). Course “Topics in Cognitive Neuropsychology” (2nd semester, 3rd year of the bachelor in Psychology). Class on reading, dyslexia, and acquired reading disorders (April, 2019).

Fernandes, T. (2019). Course “Cognitive Psychology” (2nd semester, master in Cognitive Science, ULisboa). Class on Study 1 (May, 2019).

Araújo, T. (2019). Course “Cognitive Psychology” (2nd semester, master in Cognitive Science, ULisboa). Class on Study 3 (April, 2019).

Fernandes, T. (2019). Course “Advanced Topics in Cognitive Psychology” (2nd semester, Doctoral Programme in Cognitive Science, ULisboa). Class on Study 1 (May, 2019).

Academic year 2019-2020

Fernandes, T. (2019). Course “Cognitive Neuroscience of Reading” (1st semester, master in Psychology: Social Cognition). Class on the visual adaptations necessary for learning to read (November, 2019),

Araújo, S. (2019). Developmental dyslexia and deficient letter processing (1st semester, master in Psychology: Social Cognition). Class on the visual adaptations necessary for learning to read (December, 2019),

Fernandes, T. (2020). Course “Topics in Cognitive Neuropsychology” (2nd semester, 3rd year of the bachelor in Psychology). Class on reading, dyslexia, and acquired reading disorders (April, 2020).

Fernandes, T. (2020). Course “Cognitive Psychology” (2nd semester, master in Cognitive Science, ULisboa). Class on Study 1 (March, 2020).

Araújo, T. (2020). Course “Cognitive Psychology” (2nd semester, master in Cognitive Science, ULisboa). Class on Study 3 (April, 2020).

Fernandes, T. (2020). Course “Advanced Topics in Cognitive Psychology” (2nd semester, Doctoral Programme in Cognitive Science, ULisboa). Class on Study 1 (March, 2020).

Academic year 2020-2021

Fernandes, T. (2020). Course “Cognitive Neuroscience of Reading” (1st semester, master in Psychology: Social Cognition). Class on the visual adaptations necessary for learning to read (October, 2020),

Araújo, S. (2020). Developmental dyslexia and deficient letter processing (1st semester, master in Psychology: Social Cognition). Class on the visual adaptations necessary for learning to read (November, 2020),

Fernandes, T. (2021). Course “Topics in Cognitive Neuropsychology” (2nd semester, 3rd year of the bachelor in Psychology). Class on reading, dyslexia, and acquired reading disorders (March, 2021).

Fernandes, T. (2021). Course “Cognitive Psychology” (2nd semester, master in Cognitive Science, ULisboa). Class on Study 1 (May, 2021).

Araújo, T. (2021). Course “Cognitive Psychology” (2nd semester, master in Cognitive Science, ULisboa). Class on Study 3 (April, 2021).

Fernandes, T. (2021). Course “Advanced Topics in Cognitive Psychology” (2nd semester, Doctoral Programme in Cognitive Science, ULisboa). Class on Study 1 (May, 2021).

Araújo, T. (2021). Course “Advanced Topics in Cognitive Psychology” (2nd semester, Doctoral Programme in Cognitive Science, ULisboa). Class on Study 3 (April, 2021).

Academic year 2021-2022

Fernandes, T. (2021). Course “Cognitive Neuroscience of Reading” (1st semester, master in Psychology: Cognitive and Social Psychology). Class on the visual adaptations necessary for learning to read (October, 2021),

Araújo, S. (2021). Developmental dyslexia and deficient letter processing (1st semester, master in Psychology: Cognitive and Social Psychology). Class on the visual adaptations necessary for learning to read (November, 2021),

Fernandes, T. (2022). Course “Topics in Cognitive Neuropsychology” (2nd semester, 2nd year of the bachelor in Psychology). Class on reading, dyslexia, and acquired reading disorders (April, 2022).

Fernandes, T. (2022). Course “Cognitive Psychology” (2nd semester, master in Cognitive Science, ULisboa). Class on Study 1 (March, 2022).

Araújo, T. (2022). Course “Cognitive Psychology” (2nd semester, master in Cognitive Science, ULisboa). Class on Study 3 (April, 2022).

Fernandes, T. (2022). Course “Advanced Topics in Cognitive Psychology” (2nd semester, Doctoral Programme in Cognitive Science, ULisboa). Class on Study 1 (April, 2022).

Araújo, T. (2022). Course “Developmental cognitive disorders” (2nd semester, 3rd year bachelor in Psychology). Class on Study 3 (May, 2022).

Curated databases | Bases de dados curadas

Fernandes, T., Arunkumar, M., & Huettig, F. (2019). Mirror-image discrimination in Tamil. OSF. <https://doi.org/10.17605/OSF.IO/BYQWJ>.

*Database relative to the behavioral results of **Study 2**, in the same-different matching tasks for investigating mirror-image discrimination and its relationship with the properties of the written system (i.e., having or not having mirrored*

letters: latin alphabet vs. tamil aksharas, respectively). Study conducted with illiterate adults (non-readers), monoliterate in Tamil and biliterate in Tamil and Latin alphabet.

Araújo, S., Domingues, M., & Fernandes, T. (2021). From hand to eye: A meta-analysis of the benefit from handwriting training in visual graph recognition. OSF Preprints.

<https://doi.org/10.31219/osf.io/quywt>.

*Database relative to the meta-analysis conducted in **Study 2**, regarding the emergence of orthographic representations and abstract letter identities that are sensitive to mirror-image differences, considering whether handwriting practice assists on this visual adaptation. In this study, a systematic literature review was conducted and the database consist of the characteristics of the studies which examined the role of handwriting training on subsequent visual symbol recognition and mirror-image discrimination.*

Fernandes, T., Xavier, E., Domingues, M., & Araújo, S. (2022). Masked priming effects by mirrored and rotated transformations of nonreversible and of reversible letters. OSF.

<https://doi.org/10.17605/osf.io/bdpq8>.

*Database relative to the raw behavioral results, scripts for analyses, and supplementary details of the behavioral experiments conducted in **Study 1**, regarding the temporal course of mirror-image discrimination during visual word and single letter recognition.*

Aguilar, M., Fernandes, T., & Domingues, M. (2021). Letter contour degradation.

<https://osf.io/gkph2/>

*Database relative to the behavioral results regarding the lexical decision task and masked priming studies investigating the early stages of orthographic processing and the degree of similarity between visual words and objects on the influence of vertices in visual recognition, part of **Study 1**.*

Outreach actions | Disseminação e divulgação de Ciência

Fernandes, T. (2018). Atualizações do conhecimento neurocientífico sobre a leitura e escrita [Update of the neuroscientific knowledge about reading and writing]. I International Meeting Mind, Brain, and Cognition (Universidade Católica Portuguesa, Lisboa, Portugal).

Outreach action organized by the Portuguese Catholic University for the academic community and laypeople about the scientific research in cognitive psychology and neuroscience with a specific focus on **Study 1**.

Raposo, A., & **Fernandes, T. (2018).** Não percas a cabeça! Desafios da Psicologia Cognitiva. [Don't loose your mind! Challenges of Cognitve Psychology] Verão ULisboa (July, 2018).

Outreach action organized by Universidade de Lisboa for high-school students about reading in the brain and mind, semantic memory, and experimental psychology.

T. Fernandes, A. Reis, & L. Faísca (2020). Aprendizagem em alunos com baixos níveis de desempenho na leitura e na escrita [Learning in students with low performance in Reading and writing]. Relatório apresentado ao Ministério da Educação: Plano Nacional de Leitura (PNL) / Edulog, Fundação Belmiro de Azevedo.

*This report was submitted to PNL, Plano nacional de leitura [National plan of reading], from the Ministry of Education, Portugal, and a summary is available at the Edulog platform: <https://ler.pnl2027.gov.pt/>. It regards the major societal implications derived from our results on the developmental trajectory in the visual adaptations necessary to reach fluent automatic reading in **Study 2**, and the deficits found since early on in developmental dyslexia that we found in **Study 3**.*

T. Fernandes (2021). <https://observador.pt/programas/nota-20/escrever-a-mao-ajuda-a-aprender/>

Outreach action: participation in the podcast Nota20, Observador (Season 3, Episode 10) about this FCT/ FEDER project and specifically **Study 2**.

T. Fernandes (2021). <https://www.rtp.pt/programa/tv/p40024/e125>

Outreach action: participation with other researchers and artists in the TV show “Sociedade Civil”, RTP2, about literacy and handwriting, where I presented **Study 2** and its potential educational implications.

T. Fernandes (2022). Diálogo Improvável. Dia do Jovem Investigador (DJIP), Faculdade de Psicologia, ULisboa.

Outreach action: participation in the faculty’s outreach activity directed to college students about research in cognitive psychology with a special focus in this FCT-FEDER project.

S. Araújo (2022). <https://www.youtube.com/watch?v=P3FH8q8GNKA>

Outreach action “Dislexia e Alfabetização” [Dyslexia and Alphabetization]: video created under the ABC initiative for dissemination of scientific work on reading, dyslexia, and literacy, with a focus on our work on **Study 3**, regarding developmental dyslexia and the impact of our results to a better understanding of literacy instruction in this cognitive disorder..

T. Fernandes (2022). Entrevista JN/Diário de Notícias (jornalista: Sofia Teixeira)

<https://www.noticiasmagazine.pt/2022/escrita-a-mao-cronica-de-uma-morte-anunciada/estilos/comportamento/271369/>