

Boris M. Velichkovsky
Pavel M. Balaban
Vadim L. Ushakov *Editors*

Advances in Cognitive Research, Artificial Intelligence and Neuroinformatics

Proceedings of the 9th International
Conference on Cognitive Sciences,
Intercognsci-2020, October 10–16,
2020, Moscow, Russia

Advances in Intelligent Systems and Computing

Volume 1358

Series Editor

Janusz Kacprzyk, Systems Research Institute, Polish Academy of Sciences,
Warsaw, Poland

Advisory Editors

Nikhil R. Pal, Indian Statistical Institute, Kolkata, India

Rafael Bello Perez, Faculty of Mathematics, Physics and Computing,
Universidad Central de Las Villas, Santa Clara, Cuba

Emilio S. Corchado, University of Salamanca, Salamanca, Spain

Hani Hagraas, School of Computer Science and Electronic Engineering,
University of Essex, Colchester, UK

László T. Kóczy, Department of Automation, Széchenyi István University,
Gyor, Hungary

Vladik Kreinovich, Department of Computer Science, University of Texas
at El Paso, El Paso, TX, USA

Chin-Teng Lin, Department of Electrical Engineering, National Chiao
Tung University, Hsinchu, Taiwan

Jie Lu, Faculty of Engineering and Information Technology,
University of Technology Sydney, Sydney, NSW, Australia

Patricia Melin, Graduate Program of Computer Science, Tijuana Institute
of Technology, Tijuana, Mexico

Nadia Nedjah, Department of Electronics Engineering, University of Rio de Janeiro,
Rio de Janeiro, Brazil

Ngoc Thanh Nguyen , Faculty of Computer Science and Management,
Wrocław University of Technology, Wrocław, Poland

Jun Wang, Department of Mechanical and Automation Engineering,
The Chinese University of Hong Kong, Shatin, Hong Kong

The series “Advances in Intelligent Systems and Computing” contains publications on theory, applications, and design methods of Intelligent Systems and Intelligent Computing. Virtually all disciplines such as engineering, natural sciences, computer and information science, ICT, economics, business, e-commerce, environment, healthcare, life science are covered. The list of topics spans all the areas of modern intelligent systems and computing such as: computational intelligence, soft computing including neural networks, fuzzy systems, evolutionary computing and the fusion of these paradigms, social intelligence, ambient intelligence, computational neuroscience, artificial life, virtual worlds and society, cognitive science and systems, Perception and Vision, DNA and immune based systems, self-organizing and adaptive systems, e-Learning and teaching, human-centered and human-centric computing, recommender systems, intelligent control, robotics and mechatronics including human-machine teaming, knowledge-based paradigms, learning paradigms, machine ethics, intelligent data analysis, knowledge management, intelligent agents, intelligent decision making and support, intelligent network security, trust management, interactive entertainment, Web intelligence and multimedia.

The publications within “Advances in Intelligent Systems and Computing” are primarily proceedings of important conferences, symposia and congresses. They cover significant recent developments in the field, both of a foundational and applicable character. An important characteristic feature of the series is the short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

Indexed by DBLP, EI Compendex, INSPEC, WTI Frankfurt eG, zbMATH, Japanese Science and Technology Agency (JST), SCImago.

All books published in the series are submitted for consideration in Web of Science

More information about this series at <http://www.springer.com/series/11156>

Boris M. Velichkovsky ·
Pavel M. Balaban · Vadim L. Ushakov
Editors

Advances in Cognitive Research, Artificial Intelligence and Neuroinformatics

Proceedings of the 9th International
Conference on Cognitive Sciences,
Intercognsci-2020, October 10–16, 2020,
Moscow, Russia

Editors

Boris M. Velichkovsky
National Research Center
“Kurchatov Institute”
Moscow, Russia

Pavel M. Balaban
Institute of Higher Nervous Activity RAS
Moscow, Russia

Vadim L. Ushakov
Institute for Advanced Brain Studies
Lomonosov Moscow State University
Moscow, Russia

ISSN 2194-5357 ISSN 2194-5365 (electronic)
Advances in Intelligent Systems and Computing
ISBN 978-3-030-71636-3 ISBN 978-3-030-71637-0 (eBook)
<https://doi.org/10.1007/978-3-030-71637-0>

© The Editor(s) (if applicable) and The Author(s), under exclusive license
to Springer Nature Switzerland AG 2021

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

Conference Invited Lectures

Language, Cognitive Systems, and the Methodology of Observation	3
Andrej A. Kibrik	

Trends and Perspectives in Cognitive Research	17
Boris M. Velichkovsky	

Cognitive Development, Skills, and Aging

Theoretical and Empirical Criteria for Selecting Cognitive Over-Performers: Data from a Primary School in Moscow	29
Elena Khoroshkova, Valeria Sizova, Anastasiia Liashenko, and Marie Arsalidou	

Perceptual-Cognitive Demands of Esports and Team Sports: A Comparative Study	36
Alyona Grushko, Olga Morozova, Mikhail Ostapchuk, and Ekaterina Korobeynikova	

The Relation Between Cognitive Flexibility and Language Production in Preschool Children	44
Ekaterina Oshchepkova, Daria Bukhalenkova, and Aleksander Veraksa	




A Digital Psychophysiological Mapping of Primary School Children with/without Learning Disabilities	56
Lyudmila V. Savchuk, Sofia A. Polevaya, Kirill N. Gromov, Alexander I. Fedotchev, Sergey B. Parin, Oksana V. Balandina, and Valeriia A. Demareva	

Theory of Mind and Behavioral Control in Children with and without Borderline Intellectual Functioning	68
Galina A. Vilenskaya and Evgenya I. Lebedeva	
Bilingualism and Reserve: Etiology of Successful Aging	75
Federico Gallo, Andriy Myachykov, and Yury Shtyrov	
Perception, Memory, and Higher Cognition	
Recognition of Visual Stimuli Which Proceeded by Socially Significant Images: An ERP Study	87
Natalia Gerasimenko, Anastasiia Kushnir, and Elena Mikhailova	
How Areas of Ventral Visual Stream Interact When We Memorize Color and Shape Information	95
Stanislav Kozlovskiy and Anton Rogachev	
The Effectiveness of Metacognitive Hints in Insight Problem Solving	101
Sergey Korovkin and Anna Savinova	
Effects of Online Repetitive Transcranial Magnetic Stimulation on the Frequency of Insights During Anagram Solving	107
Alexandra G. Poydasheva, Ilya S. Bakulin, Dmitry Yu. Lagoda, Alexei A. Medyntsev, Dmitry O. Sinitsyn, Petr N. Kopnin, Liudmila A. Legostaeva, Natalia A. Suponeva, and M. A. Piradov	
The Mirror Neuron System Activity is Higher with Personal Direct Interaction	114
Ekaterina Karimova, Sabir Burkitbaev, and Nikita Katermin	
Gender Differences in Object and Spatial Inattentional Blindness Under Working Memory Load	122
Boris B. Velichkovsky and Sofia Popova	
Effect of ‘Dry’ Immersion on Visual Illusions	128
Inna Sosnina, Vsevolod Lyakhovetskii, Konstantin Zelenskiy, Elena Tomilovskaya, and Valeria Karpinskaya	
Auditory Mechanisms for Analyzing Conspecific Movement	134
Vyacheslav A. Orlov, Vadim L. Ushakov, and Irina G. Andreeva	
Domains of Eye-Tracking Research	
Probability of Visually Perceiving Emotional Expression During Saccade is Rising, not Being Suppressed	143
Ivan Y. Zherdev and Vladimir A. Barabanschikov	

Eye Movements and EEG During Reading as Markers of Interest	153
Ksenia Shedenko, Victor Anisimov, Anastasia Kovaleva, and Alexander Latanov	
Age Features of Eye Movements in Adolescents When Reading from Various Electronic Devices	160
Mariam Bezrukikh and Vladimir Ivanov	
Dependence of Eye Movement Parameters During Sight-Reading on Pianist's Skill and Complexity of Musical Notation	167
L. A. Boyko, L. V. Tereshchenko, and A. V. Latanov	
Linear and Non-linear Patterns of Eye Movements in Lexical Search: Expert Versus Novice Language Learners	174
Anna Izmalkova, Irina Blinnikova, and Maria Rabeson	
Eye Movements in Visual Semantic Search: Scanning Patterns and Cognitive Processing Across Three Cultures	182
Maria Rabeson, Irina Blinnikova, and Anna Izmalkova	
Saccade Trajectories in the Presence of Emotional and Non-emotional Distractors	190
Nadezhda Murzyakova and Maria Falikman	
The Variety of Cognitive Decisions	
Cognitive Mechanisms of Ambiguity Resolution	201
Vera Zobotkina, Didier Bottineau, and Elena Boyarskaya	
Psychophysiological Interactions Underlying Meaning Selection in Ambiguity Resolution	213
Maxim Kireev, Alexander Korotkov, Maya Zheltyakova, Denis Cherednichenko, Valeria Gershkovich, Nadezhda Moroshkina, Victor Allakhverdov, and Tatiana Chernigovskaya	
Phonetic Ambiguity Resolution: To Be or not to Be Aware	222
Olga I. Pilatova and Victor M. Allakhverdov	
Stroop Effect: Conflict Detection and Control Strategy Factors	230
Alexey Starodubtsev and Mikhail V. Allakhverdov	
Alpha-Band Effective Connectivity During Cued Versus Implicit Modality-Specific Anticipatory Attention: EEG-Source Analysis	236
Ilya Talalay, Andrei Kurgansky, and Regina Machinskaya	
The Selected Profession as Determinant of the Flynn Effect: Specificity of Changes in the Intelligence Structure of University Students	242
Olga Razumnikova and Andrey Usol'tsev	



Linear and Non-linear Patterns of Eye Movements in Lexical Search: Expert Versus Novice Language Learners

Anna Izmalkova^(✉) , Irina Blinnikova , and Maria Rabeson 

Lomonosov Moscow State University, Moscow, Russia
mayoran@mail.ru

Abstract. In the current study linear and non-linear eye movement patterns of lexical search were distinguished, based on the combination of intersaccadic angle and saccade direction measures, which proved to differ in subjects with different vocabulary knowledge. Participants, who were classified as experts and novices by their vocabulary test score, were asked to find 10 foreign language words in letter matrices. Eye movement data – peak saccade velocity and blink rate – indicated higher level of cognitive load in subjects with lower vocabulary test results. Subjects with minor vocabulary knowledge tended to adopt a non-linear eye movement pattern, characterized by frequent change of saccade direction and lack of prevalent direction, whereas proficient language learners were more inclined to demonstrate a more structured search pattern with prevailing either horizontal or vertical directions. The results confirmed our hypotheses: subjects with lower, intermediate and higher vocabulary expertise demonstrated different performance, different rates of cognitive load markers and different eye movement patterns. The acquired data, combined with the results of our previous study, support the argument that experts’ advantage in professional tasks is mediated by cognitive control.

Keywords: Experts and novices · L2 learners · Visual search · Eye movement patterns · Intersaccadic angle · Saccade direction

1 Introduction

Features of experts’ and novices’ information processing is a challenging area of eye movement research. Experts have extensive and in-depth knowledge and skills in domain-specific areas as compared to novices. When solving cognitive tasks, they demonstrate faster and more accurate execution. The key concept of the experts-novices studies is that solving visual tasks differs in people with different level of expertise: in general, the feature of experts’ eye movements is their “fluency” of viewing and focus on relevant details, which is based on their extensive knowledge of the subject [1] and the attention distribution in favor of the target areas of interest, while ignoring irrelevant areas [2]. This common idea notwithstanding, evidence of experts’ and novices’ basic eye movement parameters seem to be domain-specific. In some cases, experts were

reported to make more short fixations, as compared to novices, e.g. in reading mathematical proofs [3], while other research report a more efficient gaze behavior indexed by lower fixation rates, e.g. as in laparoscopic surgery training environment [4, 5].

Integrative eye movement measures are often used to solve this discrepancy, such as the ratio of fixation duration and saccadic amplitudes, that characterizes the preference of either ambient or focal visual systems [6]. This metric has been used in a number of comparative studies of expert and novice cognitive performance. [7, 8]. Other possible measures of visual search task performance, which can be used to study the nature of scanning process, are the saccadic direction and intersaccadic angles [9]. This particular measuring technique was applied in this research.

Visual search in a complex environment is a common task for experts and novices in any domain. In the current research we modelled a lexical search task, where subjects were supposed to find familiar, but undefined words among randomly assigned letter charts. As visual search involves both looking (moving the gaze to new locations) and seeing (distinguishing between targets and non-targets), the identification of eye movement patterns involves defining to which degree each process was involved. As demonstrated in previous research, structured and unstructured search patterns can reflect the use of different cognitive strategies, such as the choice between looking versus seeing strategy. The latter are connected with the active managed search [10] and high cognitive control rates [11].

In our previous study [12] we defined three scanning patterns, based on the interrelation of saccade direction and intersaccadic angle. These patterns proved to be connected to the levels of impulsivity and executive or cognitive control involvement. Subjects who tended to demonstrate a steady linear eye-movement pattern (“Horizontal sequential”) also showed low Impulsivity indices. In this case, subjects’ search was organized in left-right, bottom-top manner. In contrast, the subjects with high impulsivity indices demonstrated a less structured search. Therefore, executive and cognitive control manifested itself in linear characteristics of eye movement patterns.

The question of which scanning method leads to higher performance remains open. Some studies show that unstructured search movements lead to faster responses with less error rates, while others show the opposite trends. It is also not completely clear how the scanning methods are related to the level of expertise [13]. Some authors insist that experts use less structured and more intuitive strategies, while others hold the opposite opinion.

The current study is aimed at identifying visual lexical search patterns in subjects with different expertise in foreign languages. We hypothesized that subjects will demonstrate different performance scores, different rates of cognitive load markers (peak saccade velocity, blink rate) and cognitive control in a lexical search task depending on their foreign language vocabulary knowledge. These parameters should be reflected in their eye movement patterns: linear or non-linear.

2 Method

32 Russian-speaking subjects took part in the research. Before the main task the subjects did a WAT test [14] to estimate their English vocabulary level. The subjects had to find

10 English 4-letter words in 15*15 matrices containing English letters (randomized by frequency) in 40 s (a relatively easy task for skilled English learners and a reasonably hard, but solvable one for novice learners).

All procedures performed in the study were in accordance with the ethical standards of the ethics committee of Lomonosov Moscow State University and with the Helsinki declaration.

Recorded Data. We recorded the search success rate and eye movement data. Eye movements were sampled monocularly at 250 Hz using the SMI iView X RED 4 (FireWire) tracking system with on-line detection of saccades and fixations and a spatial accuracy $< 0.5^\circ$.

Visual search patterns of eye movements were defined on the basis of saccade directions and intersaccadic angles. SMI BeGaze data about the starting (Saccade Start Location X, Y) and ending (Saccade End Location X, Y) coordinates of the saccades (identified by SMI BeGaze by velocity and acceleration thresholds) were used.

We used the procedure of saccadic direction angles computation similar to the one described by Amor et al. [9], where the horizontal angle for the i -th saccade (α_i) is computed as:

$$\arctan(\alpha_i) = \arctan(r_{i,y}/r_{i,x}),$$

where $r_{i,y} = |\text{Location End Y} - \text{Location Start Y}|$, and $r_{i,x} = |\text{Location End X} - \text{Location Start X}|$.

The obtained angles (0° – 90°) we attributed to 8 directions according to subtraction values of y_i and x_i , where $y_i = \text{Location End Y} - \text{Location Start Y}$, and $x_i = \text{Location End X} - \text{Location Start X}$. Similarly to the previous research [13], we distinguished 8 possible directions. The percent of saccades in every direction was counted up for every trial.

The angle between the i -th saccade and the successive saccade (β_i) was computed as: in case both saccades were directed upwards or both directed downwards

$$\beta_i = 180 - (|\alpha_i - \alpha_{i+1}|),$$

in case one saccade was directed upwards and the other downwards:

$$\beta_i = 180 - \alpha_i - \alpha_{i+1}$$

The percent of 0 – 45° , 45 – 90° , 90 – 135° , 135 – 180° angles was counted up for every trial.

Data Processing. The total of 288 trials was recorded. The data were calculated and subjected to factorial ANOVA using IBM SPSS Statistics 20.

3 Results

Cluster analysis was used to categorize the subjects on the basis of their WAT performance. We opted a 3-cluster solution: lower score (cluster center = 55.75, 8 subjects),

intermediate score (cluster center = 97,46, 13 subjects), higher score (cluster center = 132,06, 11 subjects). The groups varied in their verbal search performance: the average of 0.86 words was identified in the low WAT score group; intermediate WAT score group found 1.35 word per trial; 1.95 words were found on average in the high WAT score group. The differences proved to be significant ($F(2; 286) = 28.33; p < 0,01$).

Thus, it was found that subjects with a lower level of language competence demonstrate poor performance and find fewer lexical units in random letters. In addition, it was found that for this group of respondents solving the task is associated with higher cognitive load, manifested in an increase in the number of blinks and the peak saccade velocity. Subjects with lower WAT scores demonstrated higher blink rate and higher peak saccade velocity as compared to subjects with intermediate and high WAT score (see Table 1).

Table 1. Eye movement data of subjects with different vocabulary knowledge

	Blink rate (total count per trial – 40s)	Peak saccade velocity (°/s)
Low WAT score	7.4 (4.5)	212 (72)
Intermediate WAT score	4.2 (3.1)	206 (56)
High WAT score	4.1 (2.9)	169 (55)
The results are significant at	$F(2;288) = 6,6, p < 0,01$	$F(2;288) = 12,9, p < 0,01$

As it was expected, the obtained results indicated that the subjects with lower linguistic competence achieve less success and spend more effort while solving lexical problems. It was much more interesting to find out what strategies of search activity are used by people with different linguistic experience and different levels of performance, and to what extent these strategies are subject to conscious cognitive control.

In order to identify the scanning patterns, we analyzed saccadic directions and intersaccadic angles for each trial. If a saccade is represented as a vector, the horizontal angle to the x-axis is its direction, and the angle between two consecutive saccadic events is the intersaccadic angle, which is a marker of the change in eye movement direction. Further, cluster analysis was used to define search patterns based on saccade direction and intersaccadic angle measures. We opted for a 3-cluster solution, which corresponded to the 3 patterns of visual search in our previous study (see Table 2).

Therefore, three search patterns were identified: “Horizontal” - mostly horizontally oriented directions, intersaccadic angle values with little change in direction (0° – 45°), a few “backtrack” 135° – 180° angles (49 trials); “Vertical” – more vertical (mostly downward) directions, intersaccadic angle values, indicating little change of direction and occasional “backtrack” 135° – 180° angles (44 trials); “Non-linear” - a relatively even distribution of saccade directions and intersaccadic angles, with slight prevalence of horizontally oriented saccades (136 trials). The use of Non-linear pattern was associated with higher saccadic amplitude and peak saccade velocity (see Table 3).

Table 2. Cluster analysis results

	Horizontal pattern (49 trials)	Vertical pattern (44 trials)	Non-linear pattern (136 trials)
Angles 0–45° (%)	45.76	41.62	31.97
Angles 45–90° (%)	13.98	17.45	20.13
Angles 90–135° (%)	11.74	14.97	18.93
Angles 135–180° (%)	28.51	25.96	28.97
Direction right-upward (%)	24.74	15.02	17.07
Direction upward-right (%)	5.15	9.32	9.51
Direction upward-left (%)	5.04	10.47	9.59
Direction left-upward (%)	13.06	10.86	12.94
Direction left-downward (%)	17.40	12.91	14.04
Direction downward-left (%)	5.37	13.61	9.89
Direction downward-right (%)	5.65	12.94	10.20
Direction right-downward (%)	23.59	14.86	16.76

Table 3. Saccade velocity and amplitude measures in search patterns

	Peak saccade velocity (°/s)	Saccadic amplitude (°)
Horizontal	161 (37)	2.1 (1.1)
Vertical	179 (46)	2.9 (2.9)
Non-linear	202 (71)	5.5 (6.0)
The results are significant at	F(2;288) = 9,9, p < 0,01	F(2;288) = 12,9, p < 0,01

Next, using the coefficient of contingency, we attempted to find out if there was a relationship between the level of language competence and the patterns of eye movements. The coefficient of contingency between WAT score cluster and eye-movement cluster equals 0.21, $p < 0,01$ (see Table 4). The result maintains that subjects with different levels of linguistic competence use different strategies for scanning the search space. The data in Table 4 show that subjects with lower WAT score tended to use the non-linear pattern more frequently, while higher WAT results were associated with increasing use

of linear horizontal and vertical patterns. At the same time, the strategies themselves obviously differed in order and control during implementation. The implementation of a horizontal or vertical scanning pattern implied the use of a higher level of cognitive control. In contrast, the non-linear pattern reflected a chaotic, poorly controlled search.

Table 4. Crosstabulation results (n trials) for use of the patterns in subjects with different WAT score

	Low WAT score	Intermediate WAT score	High WAT score
Horizontal pattern	5.8%	19.5%	29.9%
Vertical pattern	14.7%	18.5%	21.8%
Non-linear pattern	79.5%	62%	48.3%

4 Discussion

The results of the study indicate that language expertise can be traced in eye movement patterns in visual search task. Notably, blink rate and peak saccade velocity, acknowledged markers of cognitive load [15] increase in subjects with lesser language competence, which can be attributed to the laborious vocabulary task. The obtained results correspond to the vast amount of research on the eye movement strategies of experts and novices in terms of providing eye movement evidence for higher cognitive load of novices [16], which is especially manifested in saccade metrics [17].

Although oculomotor measures have long been used in relation to search efficiency [18], expert-novice research in different domains demands introduction of novel complex eye movement patterns, such as the way of identifying structured and unstructured search patterns. In the present study subjects with lower lexical test score demonstrated more frequent use of a non-linear scanning pattern, while the use of linear patterns increased in more efficient language learners.

As shown in previous research, structures and unstructured search patterns can reflect the use of different cognitive strategies, such as choosing “looking” versus “seeing” strategy [10]. Therefore, the question, raised by the current research, is whether the revealed eye movement patterns are determined by cognitive strategies, which, in turn, are induced by experience, or whether they can be accounted for by the increased cognitive load.

The results of our previous research, where non-linear eye movement pattern was associated with higher impulsivity index [12], support the latter hypothesis to a certain extent. As higher peak saccade velocity is supposed to be related to higher cognitive load and as it has also been registered in impulsive subjects, the use of Non-linear pattern can reflect reduction of cognitive control.

The acquired data can contribute to a challenging discussion in cognitive psychology on the features of experts’ cognitive activity [19]. Although experts retrieve relevant information quicker, their execution is not entirely effortless and intuitive. However, the distinct feature of experts is the higher cognitive control, which is reflected in more structured eye movement patterns.

5 Conclusions

The present study documented eye movement features of expert and novice language learners in vocabulary search task, which a) indicate higher level of cognitive load in subjects with lower vocabulary test results (higher peak saccade velocity and blink rate in less proficient subjects) and b) different visual lexical search patterns on the basis of eye movement data on intersaccadic angles and saccade direction (which were named Horizontal, Vertical and Non-linear).

The described patterns correspond to the patterns obtained in preceding research [12], which had also been shown to correspond to cognitive control factor. The current study displayed the relation of cognitive load and the preference of using the linear and non-linear pattern. According to the empirical data, these patterns are more or less manifested in subjects according to their expertise in foreign languages.

Acknowledgements. The research is supported by the Russian Foundation for Basic Research, grant №20-013-00674 a.

References

1. Gegenfurtner, A., Lehtinen, E., Säljö, R.: Expertise differences in the comprehension of visualizations: a meta-analysis of eye-tracking research in professional domains. *Educ. Psychol. Rev.* **23**(4), 523–552 (2011). <https://doi.org/10.1007/s10648-011-9174-7>
2. Jarodzka, H., Scheiter, K., Gerjets, P., Van Gog, T.: In the eyes of the beholder: how experts and novices interpret dynamic stimuli. *Learn Instr.* **20**(2), 146–154 (2010). <https://doi.org/10.1016/j.learninstruc.2009.02.019>
3. Inglis, M., Alcock, L.: Expert and novice approaches to reading mathematical proofs. *J. Res. Math. Educ.* **43**(4), 358–390 (2012). <https://doi.org/10.5951/jresmetheduc.43.4.0358>
4. Wilson, M., McGrath, J., Vine, S., Brewer, J., Defriend, D., Masters, R.: Psychomotor control in a virtual laparoscopic surgery training environment: gaze control parameters differentiate novices from experts. *Surg. Endosc.* **24**(10), 2458–2464 (2010). <https://doi.org/10.1007/s00464-010-0986-1>
5. Vogt, S., Magnussen, S.: Expertise in pictorial perception: eye-movement patterns and visual memory in artists and laymen. *Perception* **36**(1), 91–100 (2007). <https://doi.org/10.1068/p5262>
6. Velichkovsky, B.M., Joos, M., Helmert, J.R., Pannasch, S.: Two visual systems and their eye movements: Evidence from static and dynamic scene perception. In: Bara, B.G., Barsalou, L., Bucciarelli, M. (eds.) *Proceedings of the XXVII Annual Conference of the Cognitive Science Society*, pp. 2283–2288. Lawrence Erlbaum, Mahwah (2005). <https://doi.org/10.17691/stm2019.11.4.01>
7. Blinnikova, I.V., Rabeson, M.D., Izmalkova, A.I.: Eye movements and word recognition during visual semantic search: differences between expert and novice language learners. *Psychol. Russia State Art* **12**(1), 129–146 (2019). <https://doi.org/10.11621/pir.2019.0110>
8. Kasprowski, P., Harezlak, K., Kasprowska, S.: Development of diagnostic performance & visual processing in different types of radiological expertise. In: *Proceedings of the 2018 ACM Symposium on Eye Tracking Research & Applications*, pp. 1–6. ACM, Warsaw (2018). <https://doi.org/10.1145/3204493.3204562>

9. Amor, T.A., Reis, S.D., Campos, D., Herrmann, H.J., Andrade, J.S.: Persistence in eye movement during visual search. *Sci. Rep.* **6**(1), 20815 (2016). <https://doi.org/10.1038/srep20815>
10. Watson, M.R., Brennan, A.A., Kingstone, A., Enns, J.T.: Looking versus seeing: strategies alter eye movements during visual search. *Psychon. Bull. Rev.* **17**(4), 543–549 (2010). <https://doi.org/10.3758/PBR.17.4.543>
11. Toner, J., Montero, B.G., Moran, A.: Considering the role of cognitive control in expert performance. *Phenomenol. Cogn. Sci.* **14**(4), 1127–1144 (2015). <https://doi.org/10.1007/s11097-014-9407-6>
12. Blinnikova, I., Izmalkova, A.: Modeling search in web environment: the analysis of eye movement measures and patterns. In: *International Conference on Intelligent Decision Technologies*, pp. 297–307. Springer, Cham. (2017). https://doi.org/10.1007/978-3-319-59424-8_28
13. Emhardt, S.N., Kok, E.M., Jarodzka, H., Brand-Gruwel, S., Drumm, C., van Gog, T.: How experts adapt their gaze behavior when modeling a task to novices. *Cogn. Sci.* **44**(9), 1–26 (2020). <https://doi.org/10.1111/cogs.12893>
14. O'Dell, F., Read, J., McCarthy, M.: *Assessing Vocabulary*. CUP, Cambridge (2000)
15. Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., Van de Weijer, J.: *Eye Tracking: A Comprehensive Guide to Methods and Measures*. OUP, Oxford (2011)
16. Amadiou, F., Van Gog, T., Paas, F., Tricot, A., Mariné, C.: Effects of prior knowledge and concept-map structure on disorientation, cognitive load, and learning. *Learn. Instr.* **19**(5), 376–386 (2009). <https://doi.org/10.1016/j.learninstruc.2009.02.005>
17. Keskin, M., Ooms, K., Dogru, A.O., De Maeyer, P.: Exploring the cognitive load of expert and novice map users using EEG and eye tracking. *ISPRS Int. J. Geo-Inf.* **9**(7), 429–446 (2020). <https://doi.org/10.3390/ijgi9070429>
18. Boot, W.R., Becic, E., Kramer, A.F.: Stable individual differences in search strategy? the effect of task demands and motivational factors on scanning strategy in visual search. *J. Vis.* **9**(3), 1–6 (2009). <https://doi.org/10.1167/9.3.7>
19. Gobet, F.: Three views on expertise: philosophical implications for rationality, knowledge, intuition and education. *J. Philos. Educ.* **51**(3), 605–619 (2017). <https://doi.org/10.1111/1467-9752.12253>