

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/389509680>

# Detecting Anxiety via Eye movements: a User Experience Approach to Research and Development

Conference Paper · December 2024

CITATIONS

0

READS

31

5 authors, including:



**Doaa Alrefaei**

Worcester Polytechnic Institute

15 PUBLICATIONS 22 CITATIONS

SEE PROFILE



**Gaayathri Sankar**

Worcester Polytechnic Institute

19 PUBLICATIONS 26 CITATIONS

SEE PROFILE



**Soussan Djamasi**

Worcester Polytechnic Institute

135 PUBLICATIONS 2,094 CITATIONS

SEE PROFILE



**Javad Norouzi Nia**

Central Michigan University

13 PUBLICATIONS 37 CITATIONS

SEE PROFILE

Association for Information Systems

## AIS Electronic Library (AISeL)

---

SIGHCI 2024 Proceedings

Special Interest Group on Human-Computer  
Interaction

---

2-28-2025

# Detecting Anxiety via Eye movements: a User Experience Approach to Research and Development

Doaa Alrefaei  
*Worcester Polytechnic Institute*

Gaayathri Sankar  
*Worcester Polytechnic Institute*

Soussan Djamassbi  
*Worcester Polytechnic Institute*

Javad Norouzi Nia  
*Central Michigan University*

Diane Strong  
*Worcester Polytechnic Institute*

Follow this and additional works at: <https://aisel.aisnet.org/sighci2024>

---

### Recommended Citation

Alrefaei, Doaa; Sankar, Gaayathri; Djamassbi, Soussan; Norouzi Nia, Javad; and Strong, Diane, "Detecting Anxiety via Eye movements: a User Experience Approach to Research and Development" (2025). *SIGHCI 2024 Proceedings*. 25.

<https://aisel.aisnet.org/sighci2024/25>

This material is brought to you by the Special Interest Group on Human-Computer Interaction at AIS Electronic Library (AISeL). It has been accepted for inclusion in SIGHCI 2024 Proceedings by an authorized administrator of AIS Electronic Library (AISeL). For more information, please contact [elibrary@aisnet.org](mailto:elibrary@aisnet.org).

# Anxiety via Eye movements: a User Experience Approach to Research and Development

**Doaa Alrefaei**

Worcester Polytechnic Institute  
dalrefaei@wpi.edu

**Soussan Djamasbi**

Worcester Polytechnic Institute  
djamasbi@wpi.edu

**Gaayathri Sankar**

Worcester Polytechnic Institute  
gsankar@wpi.edu

**Javad Norouzi Nia**

Central Michigan University  
noroulj@cmich.ed

**Diane Strong**

Worcester Polytechnic Institute  
dstrong@wpi.edu

## ABSTRACT

The stimuli-task paradigm plays a pivotal role in detecting attentional patterns, which form the foundation of user experience (UX) research for designing neuro-adaptive applications using eye-tracking sensors. Grounded in attentional bias theories, we propose and evaluate a stimuli-task paradigm, along with corresponding eye-movement metrics, to detect anxiety using only eye-tracking data. Our predictive model, developed for testing this paradigm, achieved an 83.3% accuracy in identifying the likelihood of anxiety presence. These results demonstrate the efficacy of our proposed paradigm and the potential of eye-movement data to reveal distinct attentional patterns between individuals with and without anxiety. Furthermore, the eye-movement metrics used in this study could be broadly applicable in detecting user engagement.

## Keywords

User experience, Eye-tracking, Anxiety detection.

## INTRODUCTION

Positive user experience (UX) plays a crucial role in the success of digital products and services in today's competitive global market (Djamasbi & Strong, 2019). To foster a positive user experience, products must engage and sustain the attention of their target users (Norouzi Nia et al., 2021). As such, attention is a fundamental unit of analysis in UX research (Djamasbi, 2014). Given that vision is the most dominant sense for sighted individuals, eye-tracking has become the gold standard for measuring user attention in UX studies (Djamasbi, 2014). While eye-tracking devices in UX research are traditionally used to measure attention as a means of testing and refining system

design (Alrefaei et al., 2023c; Norouzi Nia et al., 2021), recent studies suggest that eye-tracking data can also serve as valuable physiological input for developing smart, neuro-adaptive applications. These applications provide real-time responses by detecting users' attentional patterns (Shojaeizadeh et al., 2019; Fehrenbacher & Djamasbi, 2017; Alrefaei et al., 2023a).

Anxiety is a health symptom that significantly impacts attention (Robinson et al., 2013a; Eysenck et al., 2005; Liu et al., 2019; Matthews & MacLeod, 1998). Because anxiety is one of the most commonly diagnosed mental health issues among young adults (Lee et al., 2021), it provides a relevant and important context for UX research that focuses on the development of smart, eye-tracking-enabled applications in health and wellness. The first step in such a UX research agenda is to design effective stimuli and tasks for data collection (Alrefaei et al., 2023b).

A recent eye-tracking study tested a new stimuli-task paradigm for detecting attentional patterns to develop smart clinical decision support systems (CDSS) for identifying chronic pain via eye movements. Arguing that dynamic attention detection requires context-rich stimuli, the study used pain-related surveys to identify attentional biases between individuals with and without chronic pain. The results confirmed the paradigm's effectiveness in detecting chronic pain's impact on attention and suggested its potential for studying other health symptoms affecting selective attention. This was tested in a follow-up study exploring anxiety's impact on information processing, demonstrating that anxiety-related surveys could reveal anxiety through eye movements (Alrefaei et al., 2023b).

The combined study results suggest that visual stimuli richness is key to detecting attentional biases caused by health-related symptoms affecting attention. To explore this, we propose testing a new context-rich stimulus: reading a short text passage to elicit eye movement patterns

as anxiety biomarkers. We will conduct an eye-tracking experiment to gather data and develop a predictive model for automatically detecting anxiety while reading an anxiety-cueing passage.

## BACKGROUND

In this section we briefly discuss the literature that we used to develop our proposed stimuli-task paradigm for detecting anxiety from eye movement data.

### The Cognitive Model of Selective Attention

The cognitive model of selective attention by Mathews and Mackintosh (1998) explains how anxiety affects attention, suggesting anxious individuals focus more on threatening stimuli than neutral ones. It posits that anxiety increases sensitivity to threats, leading to biased interpretations of ambiguous situations. Mogg et al. (2000) support this theory, showing heightened vigilance toward threatening stimuli regardless of anxiety levels, suggesting that threat perception, not baseline anxiety, directs attention. Rinck et al. (2003) further reinforce the model, noting anxious individuals are more prone to distraction by threats but may struggle to disengage, risking cognitive overload. Eye-tracking studies reveal varied attentional biases in anxiety; some show anxious individuals fixating on threats, while others demonstrate gaze avoidance (Armstrong & Olatunji, 2012; Waechter et al., 2014; Rinck & Becker, 2003). These mixed results indicate that attentional bias is dynamic and complex, requiring consideration of contextual factors like stimuli-task paradigms (Clauss et al., 2022; Alrefaei et al., 2023b).

### Stimuli-Task Paradigm in Anxiety Literature

The stimulus-task paradigm in anxiety research examines attentional bias toward negative information, often using the stimulus presentation approach. In this method, participants view simple visual cues, like pairs of threat-related and neutral words or images, with exposure times ranging from 500 to 60,000 milliseconds (Wiebe et al., 2017; Bradley, Mogg, & Millar, 2000; Rinck & Becker, 2006). Attentional bias is assessed by measuring how quickly and frequently participants focus on threat-related versus neutral stimuli (Armstrong & Olatunji, 2012; Bar-Haim et al., 2007). However, the presentation paradigm faces criticism for producing mixed results. Short exposure times may not capture the complexity of attentional processes, and the lack of context-rich stimuli may miss subtle attentional patterns (Clauss et al., 2022; Alrefaei et al., 2023a).

### Our Proposed Stimuli-Task Paradigm

Our proposed stimuli-task paradigm addresses the criticisms of the presentation paradigm for capturing attentional bias in anxiety by introducing a new approach to capture the complex nature of attention. We argue that reading a short paragraph offers ample opportunities to

capture these nuances. Recent eye-tracking studies support this, showing that context-rich visual stimuli, presented without time constraints, effectively capture attentional bias (Alrefaei et al., 2023a; Alrefaei et al., 2023b). One study found that sustained attention to textual content differed significantly between individuals with and without anxiety when reading anxiety-related survey items, providing evidence that reading a context-rich passage can capture attentional bias (Alrefaei et al., 2023b).

## METHODOLOGY

This section outlines the research process, including a pre-study, eye-tracking experiment design, and eye-tracking metrics analysis, to explore the relationship between anxiety and attentional bias during a reading task.

### Developing and Testing the Proposed Visual Stimuli

To test our paradigm's effectiveness in detecting anxiety, we created a visual stimulus: a short text passage subtly cueing anxious responses while maintaining engagement. Given the common fear of stinging insects in anxiety individuals (Woźniewicz et al., 2019), we chose an article on bee intelligence, shortened it to a single paragraph, and simplified it to a seventh grade reading level for readability (Djamasbi et al., 2016a; 2016b). The passage used Arial 16-point font with 1.5 line spacing. A pre-study with ten participants from a northeastern university confirmed the passage was engaging, with some noting discomfort, aligning with literature on anxiety around stinging insects (Schmidt, 2020), validating its choice.

The main study involved 24 undergraduates (excluding pre-study participants), who read the passage while eye movements were tracked. We asked the participants to complete PROMIS 29+ v2 anxiety survey (Huang et al., 2019; Cella et al., 2010). Based on PROMIS thresholds (T-scores < 55), data were categorized into anxiety ( $n = 12$ ) and anxiety-free ( $n = 12$ ) groups. Eye movements were collected using a Tobii Pro Spectrum 600Hz device on a 23.8-inch monitor (1920\*1080 resolution). Data was processed using an Identification by Velocity Threshold (IVT) filter with a saccade velocity threshold of 30°/s and a fixation duration threshold of 100 milliseconds.

### Analysis

To quantify attention with eye movements, we first defined Areas of Interest (AOIs) within the visual stimuli (Djamasbi et al., 2014; 2019). Since the stimulus was a text passage with 6 sentences, each sentence was designated as an AOI, allowing us to closely analyze participants' gaze patterns. This segmentation provided detailed insights into how attention was distributed across the text, revealing the impact of anxiety on reading behavior. We focused on two metrics to assess attentional bias: the fixation-to-visit duration ratio (FD/VD) and the saccade-to-fixation count ratio (SC/FC). The FD/VD measures sustained attention by

evaluating the proportion of time spent focusing on content relative to total engagement time (Norouzi et al., 2021; Alrefaei et al., 2023b). The SC/FC assesses sustained attention by analyzing the balance between focus shifts and fixation frequency (Shojaeizadeh et al., 2019).

As shown in *Equation 1*, The probability of anxiety,  $P(\text{Anxiety})$ , was modeled using 12 variables (6 AOIs  $\times$  2 metrics) based on FD/VD and SC/FC metrics for the 6 AOIs, tested with logistic regression to test the predictive capacity of these metrics for anxiety detection.

$$\log \left( \frac{P(\text{Anxiety})}{1-P(\text{Anxiety})} \right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{12} X_{12} \quad (\text{Eq1})$$

## RESULT

To optimize the predictive model, we utilized a stepwise backward elimination process, systematically removing predictors with the highest p-values in each iteration. After 11 iterations, the final model retained the most significant predictors. The final fitted logistic regression model demonstrates significant predictive power, with two key predictors remaining: the fixation-to-visit duration ratio (FD/VD) for Sentence 3 and Sentence 6.

The overall model, shown in Table 1, correctly classified 83.3% of cases, highlighting its strong accuracy in detecting anxiety. The model was statistically significant, with a Chi-square value of  $\chi^2(2) = 20.61$ ,  $p = 0.000033$ , demonstrating a robust fit. The model explained 76.8% of the variance in anxiety presence (Nagelkerke  $R^2$ ). The final fitted logistic regression model.

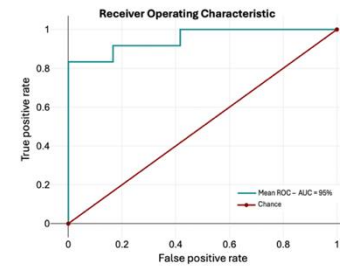
In this model, the log of the odds of detecting anxiety increases with the FD/VD ratios for both Sentence 3 and Sentence 6. As these ratios increase, the likelihood of detecting anxiety increases significantly. The intercept shows a significant value, with a coefficient ( $\beta$ ) of -74.98,  $SE = 32.17$ ,  $Wald \chi^2 = 5.43$ , and  $p = 0.0198$ , indicating that the baseline odds of detecting anxiety when all predictors are zero are low. The FD/VD ratio for Sentence 3 significantly predicted anxiety, with a coefficient ( $\beta$ ) of 71.88,  $SE = 32.18$ ,  $Wald \chi^2 = 4.99$ , and  $p = 0.0255$ . The odds ratio for this predictor is  $1.64 \times 10^{31}$ , suggesting that as the FD/VD ratio for Sentence 3 increases, the likelihood of detecting anxiety also increases. The 95% confidence interval for the odds ratio (6636.91 to  $4.06 \times 10^{58}$ ) supports this strong relationship.

Similarly, the FD/VD ratio for Sentence 6 was a significant predictor, with a coefficient ( $\beta$ ) of 19.45,  $SE = 8.84$ ,  $Wald \chi^2 = 4.84$ , and  $p = 0.0277$ . The odds ratio for this predictor was  $2.81 \times 10^8$ , with a 95% confidence interval ranging from 8.42 to  $9.39 \times 10^{15}$ , indicating a strong positive relationship between the FD/VD ratio for Sentence 6 and anxiety detection. These findings suggest that sustained attention, as measured by the FD/VD ratios for Sentence 3 and Sentence 6, is significantly associated with anxiety detection.

Coefficient	Coefficient ( $\beta$ )	Std. Error	Wald Statistic	p-value	Odds Ratio exp( $\beta$ )	95% CI for exp( $\beta$ ) Lower Bound	95% CI for exp( $\beta$ ) Upper Bound
Intercept	-74.98	32.17	5.43	0.0198	0.00000		
FD/VD_S3 Ratio	71.88	32.18	4.99	0.0255	$1.64 \times 10^{31}$	6636.91	$4.06 \times 10^{58}$
FD/VD_S6 Ratio	19.45	8.84	4.84	0.0277	$2.81 \times 10^8$	8.42	$9.39 \times 10^{15}$
Model Summary: Overall Model Chi-square test: $\chi^2(2) = 20.61$ , $p = 0.000033$ ; Nagelkerke $R^2 = 0.768$ ; Overall Accuracy: 83.3%							

**Table 1. Results of the final model from logistic regression analysis**

The Receiver Operating Characteristics (ROC) curve shown in Figure 1, provides a visual representation of the predictive model's performance, especially when distinguishing between two categories such as the presence versus absence of anxiety. The ROC curve plots sensitivity (the true positive rate) against the 1-specificity which presents the false positive rate across a range of threshold values, providing a graphical representation of model performance (Zou et al., 2007). The area under the ROC curve (AUC) serves as a summary measure of the model's overall performance. An AUC of 0.95 exhibits that there is a 95% chance that the model will correctly rank a randomly chosen positive instance higher than a randomly chosen negative instance.



**Figure 1. ROC curve**

## DISCUSSION

This study proposed and tested a new context-rich stimuli-task paradigm for detecting anxiety. Using logistic regression, we developed a predictive model based on eye movement data, specifically the FD/VD and SC/FC ratios, which accurately distinguished between individuals with and without anxiety, achieving 83.3% accuracy. These findings validate our stimuli-task paradigm's effectiveness in detecting anxiety and support the use of context-rich paradigms for assessing attentional biases (Alrefaei et al., 2023a; Alrefaei et al., 2023b). Our results showed the text passage effectively evoked anxiety's impact on attention, particularly in sentences 3 and 6, which described bees' intelligence. Sentence 3 detailed bees' problem-solving and communication, while Sentence 6 explained how bees learn to access sugar, likely intensifying anxiety in participants with a fear of stinging insects.

The FD/VD ratio emerged as a significant anxiety predictor, highlighting its ability to capture sustained attention differences in individuals with anxiety, aligning with previous research on attentional biases in anxiety contexts (Alrefaei et al., 2023b). These findings have critical implications for UX research, particularly in developing smart CDSS for health conditions affecting attention, such as anxiety and chronic pain (Alrefaei et al., 2023a; Alrefaei et al., 2024; Sankar et al., 2025). They also benefit UX research aimed at creating neuro-adaptive systems beyond clinical applications. In education, for instance, systems detecting anxiety-related patterns could tailor feedback to improve learner performance and experience. In organizational settings, such systems could detect information overload through attentional patterns (Shojaeizadeh et al., 2019; Fehrenbacher & Djamassbi, 2017). Beyond neuro-adaptive systems, our findings offer valuable insights for UX research using eye-tracking to assess design, as the metrics used here effectively quantify sustained attention, supporting the evaluation of user engagement.

#### LIMITATIONS AND FUTURE RESEARCH

Our eye-tracking experiment has limitations, notably a small, homogeneous sample composed mainly of undergraduate students without severe anxiety, which may limit the generalizability of findings to other age groups or those with more severe anxiety. Future research should involve a more diverse sample, including older adults and individuals across different anxiety levels, to better understand how these factors impact attentional biases measured by eye tracking. Additionally, this study did not account for individual differences in fear responses, such as reactions to bees, which may influence anxiety detection and generalizability. Future studies should explore varying reading materials with broader anxiety-inducing stimuli, considering individual fears and preferences to assess their effect on anxiety detection via eye movements.

#### CONTRIBUTION

Our proposed stimulus-task paradigm advances UX research by facilitating the design of eye-tracking-based systems for anxiety detection. Moreover, the findings of our study offer valuable insights for developing smart tools aimed at mental health interventions, particularly in anxiety-prone environments such as universities. By quantifying sustained attention, our results also contribute to UX research focused on evaluating user engagement with content.

#### REFERENCES

- Alrefaei, D., Djamassbi, S., Strong, D. 2023a. 'Chronic Pain and Eye Movements: A NeuroIS Approach to Designing Smart Clinical Decision Support Systems', *AIS Transactions on Human-Computer Interaction* (15:3), pp. 268–291. (doi: 10.17705/1thci.00191)
- Alrefaei, D., Sankar, G., Norouzi Nia, J., Djamassbi, S., Liu, S., Strauss, S., Gbetonmasse, S. 2023b. 'Impact of anxiety on information processing among young adults: an exploratory eye-tracking study', *Proceedings of the 56th Hawaii International Conference on System Sciences (2023)*, pp. 6321–6330. (URI: <https://hdl.handle.net/10125/103399>)
- Alrefaei, D., Zhang, L., Sankar, G., Djamassbi, S., Tulu, B., Flanagan, C., Kalayjian, A., Ge, C., Franco, C., Meraj, S., Muehlschlegel, S. 2023 c. 'Using Eye Tracking to Measure User Engagement with a Decision Aid', *Augmented Cognition, Lecture Notes in Computer Science* (vol. 14019), pp. 57–70, Springer, Cham. (doi: 10.1007/978-3-031-35017-7\_5)
- Alrefaei, D., Alharbi, R., Djamassbi, S., Strong, D. 2024. 'Clinical Decision Support System for Automatic Detection of Subjective Pain Intensity from Gaze Data', *Proceedings of the AMIA Annual Symposium* (forthcoming).
- Armstrong, T., & Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review* (32:8), pp. 704–723.
- Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & Van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychological bulletin*, 133(1), 1.
- Cella, D., Riley, W., Stone, A., Rothrock, N., Reeve, B., Yount, S., Amtmann, D., Bode, R., Buysse, D., Choi, S., Cook, K., Devellis, R., Dewalt, D., Fries, J. F., Gershon, R., Hahn, E. A., Lai, J. S., Pilkonis, P., Revicki, D., et al. 2010. 'The patient-reported outcomes measurement information system (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005-2008', *Journal of Clinical Epidemiology* (63:11), pp. 1179–1194. (doi: 10.1016/j.jclinepi.2010.04.011)
- Clauss, K., Gorday, J. Y., Bardeen, J. R. 2022. 'Eye tracking evidence of threat-related attentional bias in anxiety- and fear-related disorders: A systematic review and meta-analysis', *Clinical Psychology Review* (93), p. 102142. (doi: 10.1016/j.cpr.2022.102142)
- Djamassbi, S., Strong, D. 2019. 'User Experience-driven Innovation in Smart and Connected Worlds', *AIS Transactions on Human-Computer Interaction* (11:4), p. 215-231. (doi: 10.17705/1thci.00121)
- Djamassbi, S., Shojaeizadeh, M., Chen, P., Rochford, J. 2016a. 'Text Simplification and Generation Y: An Eye Tracking Study', *SIGHCI 2016 Proceedings*, pp. 1–12.
- Djamassbi, S., Rochford, J., DaBoll-Lavoie, A., Greff, T., Lally, J., McAvoy, K. 2016b. 'Text Simplification

- and User Experience', *Foundations of Augmented Cognition: Neuroergonomics and Operational Neuroscience, Lecture Notes in Computer Science* (vol. 9744), pp. 285–295, Springer, Cham. (doi: 10.1007/978-3-319-39952-2\_28)
12. Djamasbi, S. 2014. 'Eye Tracking and Web Experience', *AIS Transactions on Human-Computer Interaction* (6:2), pp. 37–54. (Retrieved from <https://aisel.aisnet.org/thci/vol6/iss2/2>)
  13. Djamasbi, S., Tulu, B., Norouzi Nia, J., Aberdale, A., Lee, C., Muehlschlegel, S. 2019. 'Using eye tracking to assess the navigation efficacy of a medical proxy decision tool', *Augmented Cognition: 13th International Conference, AC 2019, Held as Part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, July 26–31, 2019, Proceedings 21*, pp. 143–152, Springer International Publishing.
  14. Eysenck, M., Payne, S., Derakshan, N. 2005. 'Trait anxiety, visuospatial processing, and working memory', *Cognition and Emotion* (19:8), pp. 1214–1228. (doi: 10.1080/02699930500260245)
  15. Fehrenbacher, D. D., & Djamasbi, S. 2017. Information systems and task demand: An exploratory pupillometry study of computerized decision making. *Decision support systems*, 97, 1–11.
  16. Huang, W., Rose, A. J., Bayliss, E., Baseman, L., Butcher, E., Garcia, R. E., Edelen, M. O. 2019. 'Adapting summary scores for the PROMIS-29 v2.0 for use among older adults with multiple chronic conditions', *Quality of Life Research* (28:1), pp. 199–210. (doi: 10.1007/s11136-018-1988-z)
  17. Lee, J., Jeong, H. J., Kim, S. 2021. 'Stress, anxiety, and depression among undergraduate students during the COVID-19 pandemic and their use of mental health services', *Innovative Higher Education* (46), pp. 519–538.
  18. Mathews, A., Mackintosh, B. 1998. 'A cognitive model of selective processing in anxiety', *Cognitive Therapy and Research* (22:6), pp. 539–560.
  19. Mogg, K., Bradley, B. P. 1998. 'A cognitive-motivational analysis of anxiety', *Behaviour Research and Therapy* (36:9), pp. 809–848. (doi: 10.1016/S0005-7967(98)00063-1)
  20. Norouzi Nia, J., Varzгани, F., Djamasbi, S., Tulu, B., Lee, C., Muehlschlegel, S. 2021. 'Visual Hierarchy and Communication Effectiveness in Medical Decision Tools for Surrogate-Decision-Makers of Critically Ill Traumatic Brain Injury Patients', *Lecture Notes in Computer Science* (vol. 12776), pp. 210–220, Springer, Cham. (doi: 10.1007/978-3-030-78114-9\_15)
  21. Rinck, M., Becker, E. S. 2006. 'Spider fearful individuals attend to threat, then quickly avoid it: Evidence from eye movements', *Journal of Abnormal Psychology* (115:2), pp. 231–238. (doi: 10.1037/0021-843X.115.2.231)
  22. Robinson, O. J., Vytal, K., Cornwell, B. R., Grillon, C. 2013. 'The impact of anxiety upon cognition: Perspectives from human threat of shock studies', *Frontiers in Human Neuroscience* (7), p. 203. (doi: 10.3389/fnhum.2013.00203)
  23. Sankar, G., Djamasbi, S., & Strong, D. 2025. 'Developing Smart Clinician Support Systems from Patients' Eye Movement Data: An Exploratory Study', *Proceedings of the 58th Hawaii International Conference on System Sciences* (forthcoming)
  24. Schmidt, J. O. 2020. 'Everybody loves stinging insects!', *American Entomologist* (66:2), pp. 28–29.
  25. Shojaeizadeh, M., Djamasbi, S., Paffenroth, R. C., & Trapp, A. C. 2019. Detecting task demand via an eye tracking machine learning system. *Decision Support Systems*, 116, 91–101.
  26. Wiebe, A., Kersting, A., Suslow, T. 2017. 'Deployment of attention to emotional pictures varies as a function of externally-oriented thinking: An eye tracking investigation', *Journal of Behavior Therapy and Experimental Psychiatry* (55), pp. 1–5. (doi: 10.1016/j.jbtep.2016.11.001)
  27. Woźniewicz, A., Szykiewicz, E., Pałgan, K., Graczyk, M., Dowbór-Dzwonka, A., Bartuzi, Z. 2019. 'Fear of stinging insects in relation to state anxiety and trait anxiety in a group of patients with hymenoptera venom allergy undergoing immunotherapy', *Postępy Dermatologii i Alergologii* (36:4), pp. 472–477. (doi: 10.5114/ada.2018.78808)
  28. Zou, K. H., O'Malley, A. J., Mauri, L. 2007. 'Receiver-operating characteristic analysis for evaluating diagnostic tests and predictive models', *Circulation* (115:5), pp. 654–657.