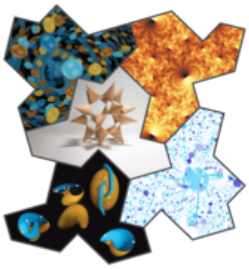

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Embodying Mathematics Without Sight: Investigating Perception–Action Loops in the Instrumented Activity of Visually Impaired Learners

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This study investigates how perception–action loops manifest within the instrumented mathematical activity of visually impaired learners assisted by digital technologies. Grounded in the Body–Artifact Functional System (BAFS) and Gibson's ecological theory of perception, the study adopts an embodied and multisensory perspective to explore alternative ways of comprehending a mathematical concept and problem–solving strategies of mathematical exercises in the absence of sight. By shifting the focus beyond a purely visual conception of mathematics, the study contributes to a more holistic conceptualization of mathematics. A secondary qualitative analysis is conducted on video–recorded task–based interviews involving two expert learners in mathematics with different degrees of visual impairment, one with partial blindness and reduced motoric skills, and one who is totally blind. Focusing on the solution of algebraic equations, the perception–action loops identified within the BAFS framework serve as the analytical lens for data examination. Thus, a two phase–analytical process is developed: (1) examining the dynamics within the three fundamental perception–action loops emerging between each pair of components of the BAFS framework, and (2) examining the dynamics within the fourth perception–action loop formed between the body–artifact entity and the environment. To operationalize this approach, for each loop an analytical instrument in the form of two–column tables is introduced to classify the characteristics and definitions associated with the components involved in the respective perception–action loop. The findings illustrate how digital artifacts mediate access to mathematical structures, support the emergence and evolution of utilization schemes, and become functionally embodied within the learner's perceptual and cognitive systems. In addition, they show that for visually impaired learners, many mathematical actions cannot be carried out without the presence of an artifact. Digital tools therefore do not merely enhance pre-existing actions; they constitute the perceptual boundary required for accessing the mathematical environment. The results highlight the critical transition from exploratory actions (Loop 3) to the emergence of a problem- solving strategy (Loop 4), marking the point at which the artifact becomes an extension of both the perceptual and cognitive system, allowing the learner to reason through the artifact. Results highlight the central role of multisensory coordination, artifact transparency, and multilevel intentionality in shaping visually impaired learners'mathematical activity. The study contributes both methodologically by proposing an applicable analytical tool for further research and teaching, and theoretically by BAFS, Instrumental Genesis, and Gibson's ecological theory toward a more inclusive and multisensory framework, with implications for accessible mathematics education and inclusive design.
Keywords: Instrumental genesis, Body–Artifact Functional System, perception–action loops, visual impairment, video magnifier, algebraic equations.

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