MULTISENSORY SYNERGIES AND DIGITAL "ACTIVE BREAKS": ENHANCING EXECUTIVE FUNCTIONS AND EMOTIONAL WELL-BEING

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ABSTRACT
This paper proposes a methodological protocol for digitally mediated Active Breaks using the Interactive Whiteboard (IWB), aimed at supporting school well-being, emotional self-regulation and executive functions within an Embodied Cognition framework (Gomez Paloma & Damiani, 2015; Diamond, 2013). Its innovative element is the use of AI as a support to, rather than a substitute for, teachers' professional judgement (Luckin, 2018), processing observational data to suggest personalised rhythmic-motor activities. The classroom is conceived as an emotionally aware and inclusive environment responsive to cognitive fatigue and barriers to participation (Lane & Schwartz, 1987; Booth & Ainscow, 2008). Given its preliminary nature, the study adopts an exploratory action-research approach to examine the feasibility and sustainability of the protocol and to collect initial evidence on the role of digital technologies in connecting bodily well-being, inclusion and educational practice.

KEYWORDS
Inclusion; active breaks; digital technologies; executive functions; embodied cognition.

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1. Introduction

The conceptualisation of the learning environment has progressively changed within pedagogical thought. Educational success is now understood as depending not only on curricular content or teaching techniques, but also on an ecosystem of factors that promote students' well-being, active engagement and self-regulation. Schools therefore have the crucial task of designing contexts capable of accommodating the complexity of contemporary classrooms and reducing barriers that may hinder learning and participation. Research shows that schools at different educational levels are progressively redesigning their spaces and practices through more flexible, dynamic and intrinsically inclusive arrangements (Booth & Ainscow, 2008; OECD, 2018; OECD, 2020). Organising an educational environment does not merely mean changing the physical classroom: it entails methodological, organisational and relational choices that shape teaching and learning. Laboratory-based teaching, active methodologies, cooperative learning and digital tools are not simply structural alternatives; they are pedagogical configurations intended to foster disciplinary and transversal competences while offering different pathways for participation and knowledge construction (Castoldi, 2020; Cottini, 2021).

Innovative teaching approaches, however, do not automatically improve the school experience. Contemporary learning environments are characterised by a continuous flow of cognitive, relational and digital stimuli that may generate cognitive overload. Mental fatigue can progressively reduce attentional resources and self-regulation, particularly in tasks requiring sustained effort and executive control (Sweller, 2011; Diamond, 2013). This issue is further complicated by the increasing heterogeneity of school populations. Current classrooms include students with different learning styles, special educational needs, neurodevelopmental disorders and neurodiverse profiles. Such plurality

calls for flexible approaches capable of responding to the variety of needs within the class group. Inclusion cannot be reduced to compensatory tools or exemptions; rather, it requires environments designed from the outset to be accessible, with methods, activities and modes of participation that value individual differences and minimise obstacles to school life (Booth & Ainscow, 2008; Cottini, 2021).

These challenges highlight the need for educational strategies that bring mind, body and emotions into dialogue while using technology to support multimodal pathways attentive to student well-being and engagement. The present contribution addresses this need by proposing a methodological protocol centred on digitally supported Active Breaks. Embodied Cognition provides the theoretical framework for structuring educational interventions intended to strengthen executive functions, emotional self-regulation and the quality of the school experience within an authentically inclusive perspective.

2. Theoretical Background: Embodied Cognition

2.1 Definition

Embodied Cognition has profoundly changed the interpretation of the relationship between body, mind and learning (Wilson, 2002). Originating in cognitive science and subsequently entering pedagogical research, this perspective moves beyond the historical mind-body divide by arguing that cognition emerges from continuous interaction among organism, environment and action (Varela, Thompson, & Rosch, 1991; Wilson, 2002). Cognitive processes cannot therefore be reduced to brain functions or conceived as detached symbolic information processing. Rather, the mind develops through the ongoing interplay of perception, action and lived experience, while the

body becomes an active component in the construction of knowledge. Lakoff and Johnson (1999) showed that language and conceptual structures themselves are rooted in bodily experience and that abstract thought develops from sensorimotor patterns and embodied ways of being in the world.

Body, mind and environment thus form a dynamic functional unity in which contextual interaction shapes cognitive representations and gives meaning to experience (Barsalou, 2008). Movement, perception and action are not merely channels for exploring the world but constitutive elements of memory, conceptualisation, reasoning and problem solving. Learning becomes an embodied process in which sensorimotor experience, emotions and cognitive activity are integrated. This theoretical shift has encouraged pedagogy to reconsider the role of the body at school. Cognitive neuroscience and educational research increasingly recognise bodily involvement as a resource for students' cognitive, relational and emotional development (Gomez Paloma & Damiani, 2015). From this standpoint, designing educational settings that value movement and sensory experience is not simply a response to the need for physical activity, but a pedagogical choice with potential implications for cognition, emotional self-regulation and classroom participation. These premises underpin research on movement in learning and, more recently, on Active Breaks as a strategy for well-being and inclusion.

2.2 From classical cognition to Embodied Cognition: a historical overview

Embodied Cognition emerged through the gradual overcoming of traditional models of mind developed during the second half of the twentieth century. In the 1950s and 1960s, early cognitivist models described the mind as a symbol-processing system strongly influenced by the computer metaphor. Cognitive processes were conceived as internal information-processing operations

largely detached from bodily experience and the context in which action occurred (Newell & Simon, 1972). Although historically influential, this approach proved insufficient to explain the situated nature of learning, the role of perception and action in knowledge construction, and the continuous exchange between individuals and their environment.

From the 1980s onward, interdisciplinary dialogue among neuroscience, philosophy of mind, psychology, linguistics and phenomenology fostered models that challenged Cartesian dualism. Varela, Thompson and Rosch (1991), through the concept of enaction, reconceptualised cognition as emerging from dynamic organism-environment interaction. Knowing no longer meant passively representing an external reality, but actively shaping meaning through action, perception and lived experience. Cognitive linguistics contributed to this shift: Lakoff and Johnson (1999) argued that language and concepts are grounded in bodily experience and that even abstract ideas develop from internalised sensorimotor patterns. Wilson (2002) later synthesised central principles of embodied cognition, emphasising its situated, distributed and action-oriented character; Barsalou (2008) examined the role of perceptual and motor simulations in conceptual processing; and Shapiro (2019) systematised the major embodied approaches by stressing the joint contribution of bodily characteristics, environmental properties and their interaction.

This change increasingly influenced educational sciences. The dialogue among pedagogy, neuroscience and learning psychology challenged the view of the body as a merely biological support for intellectual activity. In pedagogical research, Gomez Paloma and Damiani (2015) helped frame the body as a mediator of educational experience and movement as a means of simultaneously supporting cognitive development, relational competences and

emotional self-regulation. Within this framework, research on movement-based teaching and Active Breaks can be understood as a direct educational application of embodied principles.

2.3 The body as a foundation of cognitive processes

A core assumption of Embodied Cognition is the constitutive role of the body in cognition. The body is neither a mere biological substrate of mental activity nor an executive device subordinated to the brain; it is the ontological and epistemic condition within which cognition emerges and becomes organised (Varela, Thompson, & Rosch, 1991; Gallagher, 2005). Knowledge develops through dynamic interaction among perception, action and environment, so bodily experience does not simply accompany learning but helps structure its content and modes of processing (Clark, 1997; Wilson, 2002). In education, this means that movement, object manipulation, spatial exploration and sensorimotor involvement may contribute directly to the construction of cognitive representations. Acting through the body can anchor abstract concepts to perceptual-motor patterns and support embodied simulations involved in conceptual understanding, memory consolidation and transfer (Barsalou, 2008; Glenberg, 2010).

Knowledge is therefore not exclusively the product of internal symbolic operations, but the outcome of continuous co-construction between organism and environment, with meaning emerging from situated action and contextual interaction (Noë, 2004; Chemero, 2009). Perception, posture, coordination and proprioceptive, vestibular and tactile information jointly contribute to information processing, concept formation, memory, reasoning and decision making (Barsalou, 2008). Cognitive neuroscience further supports this view by showing that neural systems associated with perception and action are

recruited not only during overt movement but also in relatively abstract activities such as language comprehension, mental simulation and problem solving (Gallese & Lakoff, 2005).

The pedagogical implications are substantial. If the body participates in knowledge construction, teaching cannot be reduced to content transmission. Educational environments should assign explicit value to perception, movement and relationships. Bodily involvement is not a secondary device or a filler activity; it can function as a methodological resource for attention, meaning-making and active participation (Gomez Paloma & Damiani, 2015). The classroom can thus be conceived as a dynamic space in which cognitive, bodily and emotional dimensions influence one another, providing the theoretical basis for Embodied Learning and for methodologies that integrate movement into everyday teaching.

2.4 Embodied Learning, movement and the development of executive functions

Embodied Learning represents a natural educational development of Embodied Cognition. Learning is not conceived as a purely mental exercise but as a process integrating bodily experience, cognitive activity and continuous interaction with the environment. Movement therefore extends beyond physical exercise and becomes a pedagogical resource for knowledge construction. Bodily action can support meaning-making and conceptual understanding by allowing students to process information through concrete, contextualised and multisensory experiences (Glenberg, 2010; Gomez Paloma & Damiani, 2015). Cognitive neuroscience has likewise highlighted positive

relationships between movement and neurobiological processes involved in attention, memory and self-regulation (Ratey & Hagerman, 2008; Diamond, 2015).

Executive functions are particularly relevant because of their role in cognitive development, academic achievement and social adaptation (Diamond, 2013). They include higher-order processes that allow individuals to plan actions, voluntarily orient attention, monitor behaviour and flexibly adapt to contextual demands. Diamond (2013) identifies three core components: inhibitory control, which supports impulse regulation and goal-directed attention; working memory, which allows information to be maintained and manipulated during task performance; and cognitive flexibility, which enables strategy switching, perspective taking and behavioural adjustment. Their interaction supports more complex abilities such as reasoning, planning, problem solving and decision making. In school, executive functions contribute to reading comprehension, mathematical reasoning, writing, time management and completion of complex tasks, while also interacting with emotional self-regulation, social competence and active participation (Best & Miller, 2010; Diamond, 2013).

Research on physical activity and executive functions suggests that structured, intentional and cognitively engaging movement may be particularly beneficial. Tasks involving coordination, rhythm, balance, spatial orientation and rapid decision making require continuous planning, motor control, inhibition of automatic responses and adaptation to external stimuli (Diamond & Ling, 2016). Pesce and colleagues describe this as cognitively engaging physical activity: educational value depends not only on physical intensity but on the quality and variety of stimuli, decision making, problem solving and simultaneous coordination of body and mind (Pesce et al., 2016). This

perspective has encouraged teaching methods that intentionally integrate movement into curricular activity. Active Breaks arise within this framework as short, structured moments designed to restore attentional resources, counter mental fatigue and support self-regulation and classroom climate.

2.5 From Embodied Cognition to Active Breaks: empirical evidence and implications for inclusive education

The consolidation of Embodied Cognition has supported research on how intentional integration of movement into teaching affects students' cognitive, emotional and relational processes. Within this perspective, movement is not an interruption of study but part of the educational experience, capable of supporting cognitive processing through the simultaneous activation of motor, perceptual and executive systems. Active Breaks are among the educational practices most consistent with this view.

Active Breaks are brief movement interventions, generally lasting between five and fifteen minutes, strategically inserted into lessons to interrupt prolonged sedentary periods and restore conditions conducive to learning. Unlike ordinary recess, they are not designed solely for recreation: they can engage coordination, executive control, selective attention, rhythmic synchronisation and adaptation to external stimuli (Daly-Smith et al., 2020). Systematic reviews and meta-analyses indicate benefits for sustained attention, classroom behaviour, working memory and on-task engagement, together with reduced sedentary time and improved psychophysical well-being (Watson et al., 2017; Daly-Smith et al., 2020; Masini et al., 2020).

The strongest effects appear when movement is cognitively engaging. Research on cognitively engaging physical activity suggests that executive-function benefits depend substantially on the cognitive quality of motor experience

rather than on exercise intensity alone (Pesce et al., 2016; Vazou et al., 2019). Bimanual coordination, adaptation to visual and auditory cues, rhythm changes, sequential memory, rapid decision making and error control simultaneously recruit perceptual, motor and executive channels. Such tasks are therefore particularly relevant to the embodied assumption that the cognitive value of movement emerges from functional integration between bodily action and mental processing.

Active Breaks may also influence relational climate, motivation, emotional regulation and students' sense of self-efficacy (Norris et al., 2020). Alternating intellectual effort with short movement experiences can support management of attentional resources and contribute to a more dynamic and participatory learning context. Their intrinsic flexibility is especially relevant to inclusive education: duration, intensity, motor complexity and cognitive load can be adjusted to student characteristics. Multilevel, accessible and customisable activities can facilitate participation by students with special educational needs, neurodevelopmental disorders or neurodiverse profiles. In this sense, Active Breaks can function not only as a health-promotion strategy but also as a pedagogical device aligned with Universal Design for Learning and Inclusive Education (Booth & Ainscow, 2008; CAST, 2024; Cottini, 2021). Their effectiveness therefore depends on pedagogical design: activity selection, cognitive challenge, progression and coherence with educational objectives are decisive variables. This premise underlies the protocol proposed here, in which digital technologies and AI support the design of personalised Active Breaks linking executive functions, emotional self-regulation and inclusive participation.

2.6 Digital technologies and Artificial Intelligence in embodied and inclusive learning environments

The educational potential of Active Breaks lies not merely in introducing movement into the school day, but in the quality, progression and adaptability of their design. Developing genuinely flexible and inclusive interventions requires teachers to continuously observe, interpret and reconsider classroom dynamics. Increasing classroom heterogeneity makes this task more complex and creates a need for tools that can support, without replacing, teachers' professional decision making.

Digital technologies and Artificial Intelligence (AI) are expanding possibilities for designing, managing and evaluating learning environments. In education, however, their value should not be equated with automation of teaching. Luckin (2018), the European Commission (2022) and UNESCO (2023) emphasise their potential to support professional judgement by providing information and design possibilities that may facilitate more personalised and inclusive pathways. This human-centred approach assigns technology an instrumental role within the educational relationship, without reducing teachers' autonomy or pedagogical responsibility.

This interpretation is compatible with Embodied Cognition. If knowledge develops through the interplay of body, action and environment, digital tools acquire pedagogical legitimacy when they help create situated, multisensory and contextualised experiences. The Interactive Whiteboard (IWB) and other digital environments can support rhythmic-motor activities differentiated by duration, rhythm, coordination demands and cognitive engagement, with progressive adaptation to class needs. Visual, auditory and motor stimuli,

timely feedback and in-progress modification of activities can strengthen the multisensory dimension of teaching, making digital technology part of the learning ecosystem rather than a merely technical aid.

Technology can also assist in systematising teacher-generated observations concerning attention, participation, fatigue and peer interaction. Such information may guide subsequent pedagogical choices, for example by adjusting task complexity, introducing an Active Break or reorganising cooperative work. The purpose is not to delegate interpretation of student behaviour to an algorithm, but to facilitate the organisation and reading of data already produced through educational observation while preserving the centrality of professional judgement. This approach is consistent with the concept of an emotionally aware environment, in which emotions are recognised as integral to learning and considered in educational design (Lane & Schwartz, 1987). AI may help identify patterns that are difficult to perceive globally, providing material for pedagogical reflection without replacing the teacher's interpretive competence. Within Inclusive Education and Universal Design for Learning, learner variability becomes a starting point for educational design rather than a deficit to compensate (Booth & Ainscow, 2008; CAST, 2024; Cottini, 2021).

3. Methodological Protocol

3.1 Study rationale

The literature indicates that Active Breaks can improve attention, school engagement and processes related to executive functions. Embodied Cognition likewise emphasises the integration of bodily experience, cognitive processes and emotion in learning. Although interest in AI in education has grown rapidly,

its possible use to support the design of personalised Active Breaks consistent with Embodied Cognition and inclusive education remains comparatively underexplored. The present study therefore seeks to assess the feasibility of a model that can be transferred to everyday school practice, in which AI does not replace the teacher but supports the design of Active Breaks adaptable to class needs. Based on available evidence, the study aims to structure a learning experience oriented towards students' socio-emotional competences, assess its feasibility and sustainability, and collect preliminary data that may inform subsequent controlled studies.

3.2 Research questions

Available evidence documents positive effects of Active Breaks on attentional processes, executive functions and student well-being (Watson et al., 2017; Daly-Smith et al., 2020; Masini et al., 2020). Less is known about how these interventions can be designed and adapted to classroom characteristics while maintaining organisational sustainability, personalisation and pedagogical coherence. Similarly, despite the rapid expansion of research on AI in education (Luckin, 2018; UNESCO, 2023), studies examining AI as a support for designing Active Breaks grounded in Embodied Cognition and inclusive education remain limited. Accordingly, the present study proposes a methodological protocol that integrates these perspectives and seeks to gather initial evidence on its applicability in the school context. The protocol addresses the following research questions:

RQ1. Is the systematic introduction of digital Active Breaks organisationally sustainable within ordinary school activities?

RQ2. Does the intervention promote improvements in teacher-observed attention, participation and emotional self-regulation?

RQ3. Do students perceive improvements in their well-being and engagement during school activities?

RQ4. How does the teacher perceive the contribution of Artificial Intelligence to the design and personalisation of Active Breaks?

3.3 Expected outcomes of the proposed study

In light of the framework outlined above, the future implementation is expected to provide preliminary evidence on both observable student-related outcomes and the practical applicability of the protocol in the school context.

Primary outcomes:

- attention during teaching activities;
- participation in lessons;
- teacher-observed emotional self-regulation;
- student engagement during Active Breaks.

Secondary outcomes:

- perceived school well-being;
- appreciation of the activities;
- organisational feasibility of the protocol;
- teacher-perceived usefulness of AI.

3.4 Study design

The study adopts a single-group pre-test–intervention–post-test design. This choice reflects the exploratory nature of the research, whose primary purpose is to assess protocol feasibility before future trials involving a control group.

The intervention will last four weeks, during which Active Breaks will be integrated into ordinary teaching without altering the standard organisation of lessons.

3.5 Participants

The study will be conducted in one primary-school or lower-secondary-school class comprising approximately 10–15 students. All students in the class will be involved, including any students with Special Educational Needs, in accordance with the principles of Inclusive Education. Participation will be subject to informed parental consent.

3.6 Procedure

The intervention will be organised into three phases.

Phase 1 – Pre-test

Before the intervention, the teacher will complete an observational grid addressing attention, participation, collaboration, compliance with rules and emotional self-regulation. At the same time, students will complete a brief anonymous five-point Likert questionnaire assessing interest in school activities, perceived attention, cognitive fatigue and well-being at school.

Phase 2 – Intervention

For four weeks, two Active Breaks of approximately five minutes each will be implemented every day. Activities will include rhythmic-musical exercises, coordination games, cross-lateral movements, motor sequences to memorise,

balance activities, “stop-and-go” games and brief breathing exercises. At the end of each week, the teacher will complete a logbook recording participation, critical issues, adaptations made and perceived effectiveness of the activities.

Table 1. *Example of intervention planning*

Week	Main objective	Examples of Active Breaks	Duration	Possible AI-suggested adaptations*
1	Familiarisation with the routine and initial observation	Stop-and-go games, cross-lateral movements, simple rhythmic exercises	2 × 5 min	Reduce/increase duration; select simpler or more dynamic activities according to initial observations
2	Strengthening attention and working memory	Motor sequences to memorise, rhythmic imitation, coordination games	2 × 5 min	Introduce more complex or simplified sequences; vary rhythm and coordination level
3	Promoting collaboration and cognitive flexibility	Cooperative activities, paired motor games, rule changes (stop/go)	2 × 5 min	Adapt activities according to group participation and observed relational dynamics
4	Consolidating strategies and self-regulation	Guided breathing, integrated rhythmic-musical exercises, multisensory activities	2 × 5 min	Final personalisation based on observations collected during the intervention

** AI-generated proposals constitute design suggestions only. Selection and modification of activities remain the teacher’s responsibility.*

The proposed plan is illustrative and describes the general progression of the protocol. Activities may be adapted according to students’ age, class characteristics and observations collected during the intervention, while preserving the methodological principles underlying Active Breaks.

Operational role of Artificial Intelligence

Artificial Intelligence will not be used during activities with students and will not collect personal data. Its use will be limited to instructional design. At the end of each week, the teacher will synthesise observations collected during implementation—for example, reduced attention in the latter part of the morning, difficulties in coordination activities, or high engagement during rhythmic exercises. These summaries will be entered into a generative AI system through a structured prompt. The system will propose possible modifications for the following week, such as changes in duration, increases or reductions in motor complexity, new rhythmic-musical activities, more inclusive exercises, or adaptations for students with different educational needs.

The teacher will critically evaluate the proposals and independently decide which activities to use. AI therefore functions exclusively as a decision-support tool, while the teacher retains full responsibility for educational design. The teacher's perception of the usefulness of this support will be assessed through the weekly logbook and final questionnaire, providing information relevant to the sustainability of the protocol.

3.7 Measurement instruments

The evaluation will integrate quantitative and qualitative measures to examine both observable intervention-related changes and feasibility within the school context.

Strengths and Difficulties Questionnaire (SDQ)

Behaviour and self-regulation will be assessed using the teacher version of the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997), a widely

validated instrument available in Italian. The SDQ consists of 25 items grouped into five dimensions: emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems and prosocial behaviour. The present study will focus particularly on the Hyperactivity/Inattention and Prosocial Behaviour subscales because they are most closely aligned with the intervention objectives. The teacher will complete the questionnaire before the intervention and after the four-week implementation.

Teacher observational grid

Alongside the SDQ, a brief ad hoc observational grid will be used exclusively to monitor the intervention. It will record attention during lessons, participation in activities, engagement in Active Breaks, peer collaboration and compliance with instructions. Each indicator will be rated on a five-point Likert scale (1 = never; 5 = always). The grid has no diagnostic purpose and is intended solely to document the course of the intervention.

Student satisfaction questionnaire

Students will complete a brief anonymous questionnaire consisting of 8–10 items rated on a five-point Likert scale. It will assess appreciation of Active Breaks, perceived well-being during the school day, level of engagement and perceived attention during lessons.

Teacher logbook

Throughout the intervention, the teacher will complete a weekly logbook documenting the progress of activities, critical issues, adaptations made and perceived usefulness of Artificial Intelligence in designing Active Breaks. Qualitative data will complement the quantitative findings.

3.8 Data analysis

Quantitative data will be analysed using descriptive statistics (mean and standard deviation) and by comparing pre-test and post-test scores. Qualitative data from the teacher logbook will undergo thematic analysis to identify recurring elements concerning protocol feasibility, student participation and the contribution of Artificial Intelligence to activity design. Integrating quantitative and qualitative evidence will provide an overall assessment of intervention sustainability.

4. Conclusions

This contribution proposes a methodological protocol for integrating Active Breaks supported by digital technologies and Artificial Intelligence into the school context, using Embodied Cognition as its theoretical framework. Based on the literature reviewed, the protocol is designed to promote learning environments in which movement, cognition and emotions are treated as closely interconnected dimensions and motor activity is valued as a potential support for executive functions, emotional self-regulation and active student participation.

Methodologically, the model involves a pilot implementation organised around pre-test assessment, Active Break implementation, continuous monitoring and final evaluation. Its innovative element is the use of AI as a support for instructional design. On the basis of systematic observations summarised by the teacher, AI generates suggestions for personalising motor activities, while educational decisions remain entirely under teacher responsibility. Technology

therefore does not replace professional judgement; rather, it may extend opportunities for observation, reflection and adaptation to the needs of the class group.

The protocol is intended to be readily transferable to everyday school practice because it requires limited organisational resources and integrates short Active Breaks into ordinary lessons. The flexibility of the proposed activities allows duration, motor complexity and cognitive engagement to be adapted to different educational contexts, in line with Inclusive Education and Universal Design for Learning. As a preliminary study, its immediate purpose is to assess organisational sustainability and collect exploratory evidence that may guide subsequent experimental research. It is hypothesised that systematic use of personalised Active Breaks may support sustained attention, engagement in learning activities, emotional self-regulation and perceived well-being while assisting teachers in designing more adaptive and inclusive learning environments. Future studies with larger samples and controlled designs will be required to test effectiveness and clarify the contribution of AI to pedagogical personalisation. The proposed model should therefore be understood as an initial step towards evidence-based educational practices capable of integrating movement, digital technologies and pedagogical innovation in support of learning and well-being for all students.

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