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PROCEDURAL MEMORY AND VERBAL PRODUCTION IN CHILDREN WITH AUTISM: AN 'UNCONVENTIONAL' INTERVENTION

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ABSTRACT

Procedural memory allows us to acquire knowledge automatically and unconsciously, without paying attention, simply by experiencing it. This automaticity is the result of implicit learning, a process that initially transforms complex and conscious actions into fluid and automatic sequences such as washing and dressing, but it is also responsible for the acquisition of aspects concerning the recognition and articulation of sounds and the rules of inflexion and word combination.

Therefore, to be efficient, an intervention aimed at improving language development and the development of the various subcomponents of the system should focus on implicit learning and procedural memory. In fact, repeated exposure to rhythmic-musical stimuli, such as songs, in which some patterns or routines directly activate the emotion and reward system (history of past learning with 'lullabies'), leads to changes in behaviour or perceptions without explicit awareness, greatly improving phonatory articulation.

The study reported here was conducted with 11 subjects (8 males and 3 females aged between 2.3 and 5.1 years; average age 3.9 years) who were presented with various nursery rhymes or children's songs (activation of procedural memory). After six months of treatment, the vocal requests had increased considerably, and their intelligibility had improved significantly.

KEYWORDS: Autism Spectrum Disorder, Procedural Memory, Implicit Learning, Speech-Verbal Production.

INTRODUCTION

The two types of memory that allow us to store and access our knowledge, stored in Long Term Memory (LTM), are explicit (or declarative) memory and implicit (or non-declarative) memory (Schacter, Gilbert & Wegner, 2010).

The *explicit or declarative memory*, so named because it is linked to language, starts developing around the age of three but is not fully formed until after puberty. It is more fragile and acts when people, unconsciously or intentionally, retrieve past experiences from memory and includes *semantic* *memory*, i.e. the network of associated facts and concepts that form our general knowledge of the world, and *episodic memory*, the collection of past personal experiences that occurred at a particular time and place. The latter is the only type of memory that allows us to undertake a 'mental journey through time' (Tulving, 1972, 1983, 1999), allowing us to recall and 'relive' particular events. These two memory systems are the basis of *autobiographical memory*, which concerns the memories we have of ourselves (semantic: acontextual) and our relationship with the world around us (episodic: contextual) (Baddeley, Eysenck & Anderson, 2011).

Implicit or non-declarative *memory*, on the other hand, is acquired at a very early age, already in the foetus's brain, and lasts a lifetime. Until the age of ten months, it is the only type of memory present in the brain. Until age 6, it remains the most developed and used type of memory, even if with schooling at three years of age, we pass, often too quickly, to explicit memory (Parkin 1993). It also has some distinctive characteristics: 1) Ability to operate in the background, freeing up cognitive resources for other more complex and demanding mental activities; 2) Resistance to forgetting: once consolidated, procedures remain stable for a very long time; 3) Resisting even long periods of inactivity; 4) Implicit access: the information is automatically recalled through the action itself, without the need for conscious retrieval; 5) Gradual learning: the acquisition of procedural skills requires repeated and constant practice.

The implicit system is made up of various sub-components: for the acquisition of *cognitive-motor procedures* (the ability to walk, to articulate sounds, to drive a car, etc.), for the acquisition of *conditioned reflexes* (association between sensory stimuli and complex responses) and for *priming* (an important phenomenon concerning visual and auditory perception). Among these subcomponents, the one that is most involved in language acquisition is *procedural memory*, that is, the gradual acquisition of skills as a result of practice, or 'know-how' in doing things, such as knowing how to ride a bicycle or tie one's shoes (Sanhueza, Urrutia, M., & Marrero, 2024).

Procedural memory allows us to acquire knowledge automatically and unconsciously, without paying attention, simply by experiencing it. This automaticity is the result of implicit learning, a process that transforms initially complex and conscious actions into fluid and automatic sequences such as washing and dressing, but it is also responsible for the acquisition of aspects concerning the recognition and articulation of sounds (phonological aspects) and the rules of inflexion and word combination (morphosyntactic aspects) (Ellis, 2015). The neuronal basis of this type of memory is represented in some subcortical structures (basal ganglia of the left hemisphere, dentate nuclei of the cerebellum) and some specific areas of the cerebral cortex involved in perception (somatic and auditory) and in movement (Broca's area, supplementary motor area) (Paradis 1994; Ullman 2004; Ullman & Morgan-Short, 2023).

The process of formation and consolidation of procedural memory follows a path involving various phases, each characterised by specific neurobiological changes:

- *Cognitive phase (initial)*: the individual must pay maximum attention to every single aspect of the action to be learnt;
- *Associative phase (intermediate)*: movements begin to flow more smoothly, and errors progressively decrease thanks to the formation of increasingly efficient neural connections;
- *Autonomous phase (final)*: the action becomes completely automatic thanks to the creation of stable dedicated neural networks.

Several studies (Koch, Sundqvist, Birberg Thornberg, et al., 2020; Sanhueza, Urrutia, & Marrero, 2024) have demonstrated the importance of procedural memory in certain areas of development, for example, in motor, social, cognitive and linguistic abilities. This occurs both in early childhood and in later stages of development and affects both children with typical development and children with neurodevelopmental disorders. In fact, studies document an increase in rhythmic arm movements during the suckling phase and a decrease once this phase is over. The two rhythmic activities, motor and linguistic, share the same pattern based on movement coordination skills and personal characteristics: each child follows his or her own rhythm based on his or her behavioural repertoire. Motor skills can, therefore, influence both the quantity and the type of interaction opportunities that children have with others and, consequently, the development of language and social relationships. To learn to speak, children must discover the rules of their language by implementing specific cognitive strategies: cognitive problems can, therefore, affect the development of language, both in comprehension and production (Jackson, Leitão, Claessen, & Boyes, 2020; Ullman, Earle, Walenski, & Janacsek, 2020).

If these aspects are crucial for many children with typical development, they are even more so for those with neurodevelopmental disorders. In fact, in the presence of linguistic difficulties in preschool and at the beginning of schooling, it is of fundamental importance, both for setting up rehabilitation and for making a prediction of the clinical course, to evaluate not only linguistic functioning but also motor, mnemonic, executive functions, etc., and the child's ability to relate to attachment figures (Rondal, Perera & Spiker, 2011; Perruchet & Poulin-Charronnat, 2015).

Therefore, in order to be effective, an intervention aimed at improving language development, as well as improving the development of the various subcomponents of the system, should follow the following principles (Rondal & Guazzo, 2012):
1. it should be practised in everyday speech, avoiding recourse to formal and functional categories, abstract rules and other metalinguistic languages;
2. it should favour the direct mapping of the pragmatic semantic framework onto the sequential and distributive models of syntactic lexemes and morphemes;
3. the learning environment should reduce the demands on the procedural system, breaking down complex sequences into component parts and gradually recombining them into larger units;
4. the rate of speech addressed to the child should be reduced and the natural pauses between sentences and clauses should be slightly exaggerated to emphasise the organisation of the sentence surface;

5. the construction of paradigmatic repertoires should be favoured through analogical substitutions of lexical groups, sentences and clauses;
6. the level of intensity of the linguistic input should be slightly increased to focus the children's auditory attention.
7. the input should be provided rhythmically to emphasise the distribution of words in sentences.

From these principles, it is clear that repeated exposure to rhythmic-musical stimuli, such as songs, in which some patterns or routines directly activate the emotion and reward system (history of past learning with ‘lullabies’), leads to changes in behaviour or perceptions without explicit awareness, improving, for example, phonatory articulation. The brain areas often involved include, in particular, the motor cortex and the prefrontal regions, which work together to integrate this new knowledge without supervising executive functions.

Method

Participants

The participants were 11 Italian children (eight boys and three girls), aged between 2,3 and 5,1 years, with level two autism spectrum disorder (DSM-5); they were non-speaking children, able to use essentially motor and behavioural communication or using one (Paolo, Marco, Lina and Marco), two (Lucio, Ciro and Pino) and three (Rosa) vocal requests (Mand); while three subjects (Luca, Matteo and Angela) had no vocal Mand. In addition, all the children showed difficulties in speech articulation (VB-MAPP; Sundberg, 2008). All participants were assessed in a natural environment.

Procedure

All subjects were initially evaluated (baseline) by three adults (professionals and non-professionals), and only when the word produced was intelligible to all was it recorded as correctly produced; in other cases, even if the parents understood it, it was not considered a ‘clear request’.
The experimental design used is indicated by the letters AB, where A indicates the baseline measurement phase and B that of the treatment and each phase is evaluated in relation to the one that precedes or follows it. The effects are demonstrated in the change in level and trend of the data, depending on the introduction: the more evident the change in the data between the treatment phases, the more credible and verifiable the effectiveness of the intervention. AB experimental designs also prove the relationship between independent (treatment) and dependent (observed behaviour) variables. In this study, we used an A-B-B+C experimental design where A is the baseline measurement, B is the intervention with only vocal Mand, and B+C is the intervention of vocal Mand + the use of songs and nursery rhymes (Fig. 1).

Subsequently, on the advice of the operators, parents (especially the mother) began to produce songs in the presence of their children (such as ‘Old MacDonald’, nursery rhymes (such as ‘Twinkle Twinkle Little Star’) and onomatopoeic sounds (such as ‘Knock knock’, ‘Clap’, etc.), initially demanding visual attention and then starting to sing while the children paid attention to something else. In the latter situation, almost all the children shifted their interest and attention from what they were doing to the

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person singing. In contrast, while continuing to do what they were doing, the others began to move, reproducing the same movements ('dancing') as when they had listened to the song, paying attention to the person singing. These responses had a considerable influence on both the rhythm and the refinement of the perceptive-motor skills that were then used for spontaneous language acquisition. In fact, after a few weeks of these 'procedures' the children began to produce, implicitly and spontaneously, some very intelligible words (excluding the intervention of the Executive Functions: 'singing circuit'), even if they were not contextualised and if the incredulous parents tried to encourage their child to repeat the word they had just heard (activating the intervention of the Executive Functions: 'speech circuit'), the child was unable, despite their best efforts, to use their speech organs to reproduce the word.

After a few months, while continuing the treatment and also exposing the children to cartoons in which songs, nursery rhymes and onomatopoeic sounds acted as a soundtrack, all the children began to produce several words that were intelligible to all possible interlocutors and well-contextualised, as can be seen in Table 1 and Fig. 1.

RESULTS

After about six months of treatment, as can be seen from the graph in Fig. 1, the language, in terms of the number of words produced in a contextual and intelligible way, has improved in all the children considered in this study. From the baseline (A), 3 children did not use any words, 4 used only one word, 3 children used 2 words, and only one child used 3 words.

In experimental phase B, vocal mand was introduced, slightly improving the number of words (one or two words) for all the children. In contrast, in experimental phase B+C, in which *songs and nursery rhymes* (implicit learning) were added to the vocal mand, the improvement was very evident (Tab. 1).

NUMBER OF WORDS PRODUCED IN THE THREE PHASES OF THE PROJECT											
PHASES	Luca	Matteo	Paolo	Lina	Angela	Mario	Lucio	Pino	Rosa	Ciro	Marco
BASELINE	0	0	1	0	0	1	2	2	3	2	1
	0	0	1	0	0	1	2	2	3	2	1
	0	0	1	1	0	1	2	2	3	2	1
	0	0	1	1	0	1	2	2	3	2	1
	0	0	1	1	0	1	2	2	3	2	1
	0	1	1	1	0	1	2	2	3	2	1
VOCAL MANDS	1	1	2	1	0	2	2	3	3	2	1
	1	2	2	1	0	2	2	3	3	2	1
	1	2	2	1	1	2	3	3	3	2	2
	2	2	2	1	1	2	3	4	3	2	2
	2	2	2	1	1	2	3	4	4	2	2
	2	2	2	1	1	2	3	4	4	2	2
	2	2	2	1	1	2	3	4	4	2	2
	2	2	2	1	1	2	3	4	4	2	2
	2	2	2	1	1	2	3	4	4	2	2
	2	2	2	1	1	2	3	4	4	2	2
VOCAL MANDS + IMPLICIT LEARN.	10	9	7	9	7	10	10	10	9	9	8
	10	10	9	11	7	10	12	12	10	9	10
	10	10	9	11	8	10	13	12	11	10	10
	11	11	10	11	9	11	13	14	13	10	11
	11	10	12	12	10	11	13	14	12	10	12
	24	22	19	20	23	24	32	31	28	29	32
	28	27	24	27	30	30	38	41	36	37	39
	30	29	28	32	35	36	45	49	44	45	47
	50	56	51	49	52	49	52	57	52	52	55

Tab. 1 – Number of words produced in the three phases of the intervention: 'Baseline', 'Vocal mands ' and 'Vocal mands + Implicit learning'.

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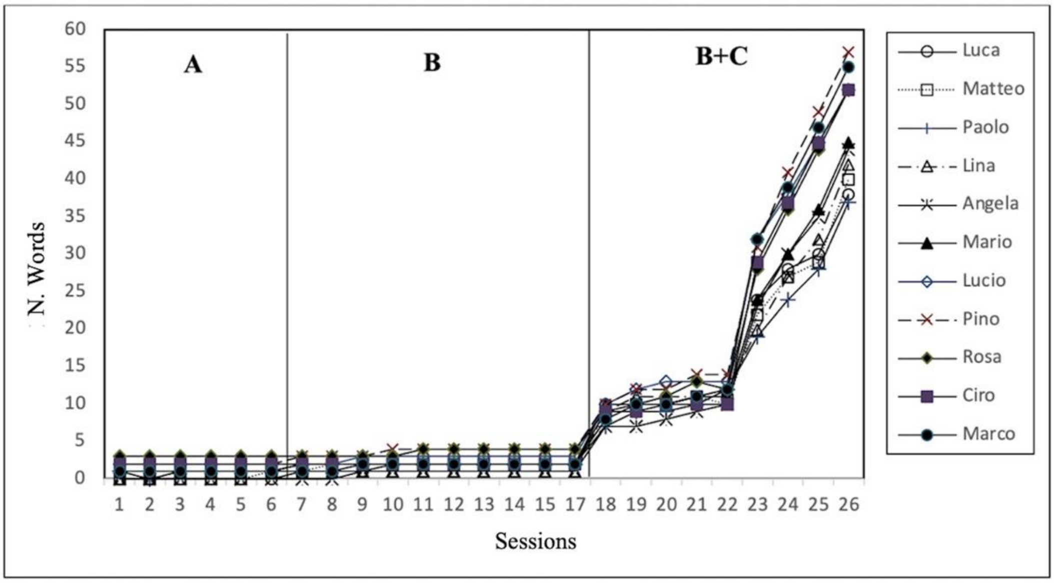

Fig. 1 - The graph shows the improvement in speech, by number of words, in all children considered in this study. From baseline (A), three children do not use words, four use one word, three use two words, and only one use three words. In experimental phase B, 'Vocal Mands' was introduced, with a slight improvement per number of words for all children except Angela and Marco. In contrast, in experimental phase B+C, 'Songs and nursery rhymes' were added to the 'Vocal Mands' (implicit learning), and the improvement was very conspicuous.

CONCLUSIONS

When a child is born, he has a sensory apparatus and a cognitive system that allows him to listen to and process linguistic stimuli. Thanks to this equipment, he is able to implement that form of 'automatic' learning of linguistic structures called 'implicit learning', which is unconscious and takes place thanks to experience. This implicit process, which transforms complex and conscious actions into fluid and automatic sequences, is also responsible for acquiring aspects concerning the recognition and articulation of sounds (phonological aspects) and the rules of inflexion and word combination (morphosyntactic aspects).

Therefore, in the presence of difficulties in language learning, especially in children with atypical development, repeated exposure to rhythmic-musical stimuli, such as songs, in which some patterns or routines directly activate the procedural memory system, leads to changes in behaviour without explicit awareness, improving, as in the subjects considered in this study, phonatory articulation (Patel, 2008).

In fact, using songs and nursery rhymes has refined the intelligibility of words and their incrementation. It has also improved speech perception, expressive language skills and the meaning of words (Torppa & Huotilainen, 2019).

REFERENCES

Baddeley, A.D., Eysenck, M.W. & Anderson, M.C. (2009). *Memory*. Hove, UK: Psychology Press.

Ellis, N. (2015). Implicit and explicit language learning. In P. Rebuscat, (Ed). *Implicit and esplicit learning of language* (pp. 3-23). Amsterdam, NL: John Benjamin Publishing Company.

Jackson, E., Leitão, S., Claessen, M.; Boyes, M. (2020). Working, declarative, and procedural memory in children with developmental language disorder. *J. Speech Lang. Hear. Res.*, 63, 4162–4178.

Koch, F.-S., Sundqvist, A., Birberg Thornberg, U., Nyberg, S., Lum, J.A.G., Ullman, M.T., Barr, R., Rudner, M., & Heimann, M. (2020). Procedural memory in infancy: Evidence from implicit sequence learning in an eye-tracking paradigm. Journal of Experimental Child Psychology, 191, 1-4. DOI:org/10.1016/j.jecp.2019.104733.

Paradis, M. (2004). *Neurolinguistic theory of bilingualism.* Amsterdam, NL: Benjamins.

Parkin, A.J. (1993). *Memory: Phenomena, experiment, and theory.* Hoboken, NJ: Blackwell Publishing.

Patel, A.D. (2008). *Music, language, and the brain*. Oxford, UK: Oxford University Press.

Perruchet, P., & Poulin-Charronnat, B. (2015). The learnability of language. In P. Rebuscat, (Ed). *Implicit and esplicit learning of language* (pp. 3-23). Amsterdam, NL: John Benjamin Publishing Company.

Rebuscat, P. (2015) (Ed.). *Implicit and esplicit learning of language* (pp. 3-23). Amsterdam, NL: John Benjamin Publishing Company.

Rondal, J.A., & Guazzo, G.M. (2012). Morphosyntactical Difficulties and Rehabilitation in Down Syndrome". *International Review of Research in Developmental Disabilities* (R. Hodapp, Editor), 42, New York: Elsevier 2012, 85-107

Rondal, J.A., & Guazzo, G.M. (2021). La sindrome di Down: Conoscenze attuali e prospettive di cura. Roma: Anicia.

Rondal, J.A., Perera, J., & Spiker, D. (2011). *Neurocognitive rehabilitation in Down syndrome.*

The early years. Cambridge, UK: Cambridge University Press.

Sanhueza, S., Urrutia, M., & Marrero, H. (2024). Procedural Memory Deficits in Preschool Children with Developmental Language Disorder in a Spanish-Speaking Population. *Brain Sciences*, *14*(3), 198-214. DOI: org/10.3390/brainsci14030198

Schacter, D.L., Gilbert, D.T., Wegner, D.M. (2007). *Psychology*. Duffield, UK: Worth

Publishers.

Sundberg, M.L. (2008). ***VB-MAPP: Verbal Behavior Milestones Assessment and Placement Program*****. Concord, CA: AVB Press.**

Torppa, R., Huotilainen, M. (2019). Why and how music can be used to rehabilitate and develop speech and language skills in hearing-impaired children. *Hearing Research*. Sep 1; 380: 108-122. DOI: 10.1016/j.heares.2019.06.003. Epub 2019 Jun 25. PMID: 31265971.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds), *Organization of memory*. New York: Academic Press, pp. 381-403.

Tulving, E. (1983). *Elements of episodic Memory*. Oxford: OUP.

Tulving, E. (1999). On the uniqueness of episodic memory. In L.G. Nilsson & H.J. Markowitsch, *Cognitive Neuroscience of Memory*. Gottingen: Hogrefe & Huber, pp. 11–42.

Ullman, M.T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition*, 92(1-2), 231-270.

Ullman, M.T., Earle, F.S., Walenski, M., & Janacsek, K. (2020). The Neurocognition of Developmental Disorders of Language. *Annu. Rev. Psychol.*, 71, 389–417.

Ullman, M.T., & Morgan-Short, K. (2023). How the declarative and procedural memory brain circuits support second language: Electrophysiological, neuroimaging, and neurological evidence. In *The Routledge Handbook of Second Language Acquisition and Neurolinguistics* (pp. 165-176). Routledge.