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CAN COMPENSATORY PROCESSING ACCOUNT FOR THE PERFORMANCE OF INDIVIDUALS WITH AUTISM SPECTRUM DISORDERS IN IMPLICIT LEARNING TASKS? A FOCUSED MINI-REVIEW

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ABSTRACT. The research literature provides numerous hypotheses aiming to isolate the cognitive mechanisms thought to underlie the social impairments of individuals with autism spectrum disorder (ASD). To this end, the hypothesis of an implicit learning (IL) deficit in ASD, posits that individuals with ASD encounter social difficulties because, contrary to individuals with typical development (TD), they are unable to implicitly, or unconsciously, learn social grammars (i.e., social regularities). However, the majority of the available research indicates a general lack of empirical support for this hypothesis. Our chief objective is to inform future research by reviewing some of the most salient findings from the IL deficit in ASD literature from a compensatory processing framework. In order to achieve our goal, we initially detail the rationale behind the IL deficit in ASD hypothesis. Then we summarise several research findings which either confirm or fail to confirm this hypothesis. Subsequently, we introduce the concept of compensatory processing. Afterwards, we review a series of evidence indicating that individuals with ASD might compensate in some IL tasks. Here we suggest that even though their behavioural performance seems intact, the functioning of IL in ASD is likely to be atypical. Finally, on the basis of the literature review, we suggest potential directions for future research into this hypothesis.

Keywords: *autism spectrum disorders; implicit learning; compensation.*

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1. Introduction

According to the Diagnostic and Statistical Manual of Mental Disorders, DSM-V (American Psychiatric Association, 2013), autism spectrum disorders (henceforth, ASDs) are a group of neurodevelopmental disorders characterized by impairments in social interaction and communication, as well as repetitive behaviours and restricted interests or activities. According to the latest report of The Autism and Developmental Disabilities Monitoring (ADDM) Network, the prevalence of ASD is now estimated to be of one in 59 children (Baio, et al., 2018). In this context, improvements in the efficacy and effectiveness of psychological interventions in ASD is of paramount importance. A detailed understanding of the underlying cognitive mechanisms of ASD is necessary in order to improve the efficacy and effectiveness of psychological interventions. However, despite massive systematic efforts, understanding those mechanisms remains a great challenge for cognitive scientists and practitioners.

With regard to the potential causes which might generate the social difficulties of individuals with ASD, the scientific literature provides several promising areas of research. This paper is focused on reviewing literature from two subdomains of ASD research. Namely, research which evaluates the functioning of implicit learning (henceforth, IL) in ASD and research which evaluates compensatory processing in ASD (i.e., in brief, compensatory processing occurs when a typical performance in a cognitive task is achieved through the recruitment of additional cognitive and/or neurobiological resources which are not recruited by individuals with typical development). Our general scope is to inform future investigations into the functioning of IL in ASD by bridging those two areas of research. In order to achieve this goal, in the next section, we will discuss the reasoning behind the IL deficit in ASD hypothesis.

2. The functioning of IL in individuals with ASD, why does it matter?

On the one hand, individuals with ASD exert atypical social behaviours. For instance, if a person with ASD enters a room and observes someone doing complex computations, he/she might not have that instant feeling that he/she shouldn't speak loudly. Such rapid social judgements, or social intuitions, are believed to be formed on the basis of some "social grammars" which are learned by means of observation and interaction with the surrounding environment.

On the other hand, human learning can be placed on an implicit-explicit continuum (Reber, 1967, 1989, 1993). In broad, IL, as opposed to explicit learning, refers to the unintentional acquisition of knowledge which is unavailable to awareness, (i.e., cannot be verbalised or controlled intentionally) nevertheless, the learned information affects the learner's behaviour (Cleeremans, Destrebecqz, & Boyer, 1998; Cleeremans & Jiménez, 2002). Extensive literature suggests that IL is the process responsible for learning the aforementioned "social grammars". For instance, implicitly learned information serves as the cognitive substrate of intuitive judgments (Dienes & Scott, 2005; Kuhn & Dienes, 2005; Mealor & Dienes, 2013; Pacton, Perruchet, Fayol, & Cleeremans, 2001) and implicit social cognition (Heerey & Velani, 2010; Lieberman, 2000; Norman & Price, 2012; Raab & Johnson, 2008).

Considering that individuals with ASD have impairments in social cognition and IL plays an important role in the formation of social cognition, researchers investigated if a deficit in IL can explain the social cognition impairments of individuals with ASD. Without being exhaustive, in the next section we will review some key investigations testing this hypothesis.

3. Is IL impaired in individuals with ASD?

A large set of empirical studies tested the IL deficit in ASD hypothesis by applying diverse experimental tasks (see Table 1). Nevertheless, the literature is characterised by heterogeneous conclusions; with some studies finding a deficit and others finding a normal functioning of IL in ASD.

Table 1.
Classification of studies assessing IL in ASD based on their experimental paradigm

Experimental paradigm	Study
Serial Reaction Time (SRT)Task	*Brown, Aczel, Jiménez, Kaufman, and Grant (2010); *Gordon, and Stark (2007); Izadi-Najafabadi, Mirzakhani-Araghi, Miri-Lavasani, Nejati, and Pashazadeh-Azari (2015); *Mostofsky,

	Goldberg, Landa, and Denckla (2000); *Müller, Cauich, Rubio, Mizuno, and Courchesne (2004); Sharer, Mostofsky, Pascual-Leone, and Oberman (2016); Travers, Kana, Klinger, Klein, and Klinger (2015); *Travers, Klinger, Mussey, and Klinger (2010); Zwart, Vissers, van der Meij, Kessels, and Maes (2017)
Alternating Serial Reaction Time (ASRT) Task	*Barnes, Howard Jr, Howard, Gilotty, Kenworthy, Gaillard, and Vaidya (2008); *Nemeth, Janacsek, Balogh, Londe, Mingesz, Fazekas, ... & Vetro (2010); Virag, Janacsek, Balogh-Szabo, Chezan, and Nemeth (2017)
Contextual Cueing	*Barnes, Howard Jr, Howard, Gilotty, Kenworthy, Gaillard, and Vaidya (2008); *Brown, Aczel, Jiménez, Kaufman, and Grant (2010); *Kourkoulou, Leekam, and Findlay (2012); *Travers, Powell, Mussey, Klinger, Crisler, and Klinger (2013)
Pursuit Rotor	*Gidley Larson and Mostofsky (2008); *Limoges, Bolduc, Berthiaume, Mottron, and Godbout (2013)
Virtual Pursuit Rotor	Sparaci, Formica, Lasorsa, Mazzone, Valeri, and Vicari (2015)
Artificial Language Learning Task	Mayo and Eigsti (2012)
Social Judgement Task	Schipul, Williams, Keller, Minshew, and Just (2011)
Shape Learning Paradigm	Jeste, Kirkham, Senturk, Hasenstab, Sugar, Kupelian, ... & Paparella (2015)
Dot pattern prototype learning task	Schipul, and Just (2016)
Hierarchical Figures Task	Hayward, Shore, Ristic, Kovshoff, Iarocci, Mottron and Burack (2012)
Visual Search Task	Jiang, Capistrano, Esler and Swallow (2013)
Category Learning Task	Mercado III, Church, Coutinho, Dovgopoly, Lopata, Toomey, and Thomeer (2015)

Note: studies marked with an "*" were included in the meta-analysis of Foti, De Crescenzo, Vivanti, Menghini, and Vicari (2015).

For instance, Nemeth et al. (2010) compared 13 children with ASD with 13 age matched children with typical development (henceforth, TD) and 14 IQ matched children with TD on a procedural learning task. The procedure occurred in two phases (i.e., the Learning session and the Test session) separated by an interval of approximately 16 hours. In the Learning phase, on each trial, an animated dog's head appeared on one of four possible spatial locations of a computer screen. Participants were instructed to respond as fast and as accurately as possible to each apparition by pressing its corresponding key. The Learning phase was 20 blocks long. Each block consisted of 85 trials. Unknown to participants, the target stimulus (i.e., the dog's head) respected a complex pattern. On each block the stimulus appeared randomly for the first 5 trials then, for the remainder of trials, it respected an 8-element long sequence. In the sequence 4 apparitions were pattern events which alternated with 4 events determined randomly. In the Test phase, participants completed 5 blocks identical with those from the Learning phase. In both phases, learning was operationalised as the difference in the reaction times between the pattern and random trials. In this experiment, Nemeth et al. (2010) found no differences between groups. Moreover, the authors reported that participants with ASD demonstrated an intact overnight memory consolidation of the implicitly learned information. Relatedly, with a modified version of the same procedural learning task, Virag, Janacsek, Balogh-Szabo, Chezan, and Nemeth (2017) found that when compared with children with TD, children with ASD had an increased implicit procedural learning ability.

However, the literature also provides evidences of an implicit procedural learning deficit in individuals with ASD. For instance, Mostofsky, Goldberg, Landa, and Denckla (2000) compared the performances of 11 participants with ASD and 17 age-and-IQ-matched individuals with TD on the Serial Reaction Time Task. The procedure used by Mostofsky, Goldberg, Landa, and Denckla (2000) was relatively similar with the one applied by Nemeth et al. (2010); though several differences exist. For instance, in Mostofsky, Goldberg, Landa, and Denckla (2000) the target stimulus was a circle instead of a dog's head. Also, in this study, participants completed 5 acquisition blocks, each consisting in 80 trials. In the first and last blocks, the stimuli appeared randomly. However, unknown to participants, in blocks 2 through 4, a 10 element sequence was repeated eight times per block. Learning was operationalised as the differences in reaction times in the random versus sequence blocks. In this study, the authors provide evidences for a deficit in procedural learning in children and adolescents with ASD. The reasons for which the relatively similar methods of Mostofsky, Goldberg, Landa, and Denckla (2000) and Nemeth et al. (2010) generated different results is unclear. However, we speculate that the relatively low sample size of both studies might have contributed in this sense.

Considering the mixed evidence in the literature, Foti, De Crescenzo, Vivanti, Menghini, and Vicari (2015) conducted a quantitative systematic review. Authors searched for studies investigating IL in individuals with ASD. The authors analysed studies in which: a) the individuals included in the ASD group were diagnosed in accordance with DSM III, DSM III-R or DSM IV (American Psychiatric Association, 1981, 1987, 1994) diagnosis criteria for ASD; b) there was a comparison sample of individuals with TD; c) there was a matching of the participants from the two groups in terms of their IQ, age and gender. Eleven studies were included in Foti et al.'s (2015) meta-analysis. Four hundred and seven individuals participated in those studies; 177 were diagnosed with ASD and the rest served as age, gender and IQ matched controls. Studies investigated the functioning of IL by applying four well established IL research paradigms (for a classification, see articles marked with an * in Table 1). After conducting the analysis, Foti et al. (2015) found no between groups differences in terms of IL functioning. The authors concluded that "individuals with ASD can learn implicitly, supporting the hypothesis that IL deficits do not represent a core feature in ASDs" (Foti et al. 2015, p.8).

In sum, by analysing behavioural studies, Foti et al. (2015) found no evidences of an IL deficit in ASD. However, behavioural evidences do not necessarily capture the complexity of ASD's cognitive profile. For example, as suggested by Livingston and Happé (2017), in some cases an individual with ASD can display a typical behavioural functioning which is sustained by an atypical cognitive functioning. In the next section we will discuss the dynamic of the behavioural phenotype of ASD and a potential mechanism of change (i.e., compensatory processing). This will allow us to analyse some available research on the IL deficit in ASD hypothesis from a compensatory processing framework; and finally will allow us to formulate some future research directions for this hypothesis.

4. Behavioural change and compensation in ASD

The behavioural phenotype of individuals with ASD is not necessarily stable across development. Symptoms may alleviate or worsen from childhood to adulthood (for a qualitative review, see Magiati, Tay, & Howlin, 2014). However, the mechanisms that determine the amelioration and/or worsening of symptomatology (i.e., changes of an individual relative to its own and/or his group's anticipated trajectory) across development remains a hot topic for debate and research (Georgiades, Bishop, & Fraizer, 2017).

The concept of compensatory processing - introduced by Livingston and Happé (2017) - seems useful in explaining both symptoms alleviation and worsening in ASD. As a conceptualization, the authors propose that compensatory processing occurs when an individual with ASD demonstrates a typical performance in an assessed behaviour, however his performance is sustained by the recruitment of additional cognitive and/or neurobiological resources which are not typically recruited in individuals with TD.

With regard to symptoms' alleviation, the authors advance two alternative mechanisms. First, the autistic behavioural phenotype may ameliorate in adulthood due to genuine remedies at the cognitive and / or neurobiological phenotype. Alternatively, apparent improvements in the behavioural phenotype may actually be sustained by a series of compensatory strategies - which aid to an enhanced behavioural presentation of symptomatology - despite persisting cognitive and/or neurobiological impairments (see Mukaddes, Mutluer, Ayik, & Umut, 2017). Thus, compensatory processing may explain why some individuals with ASD cease to meet diagnostic criteria when they reach adulthood (Georgiades, Bishop, & Fraizer 2017). Compensatory processing might also account for cases in which symptoms worsen across development or, cases in which individuals receive an ASD diagnosis only when they reach maturity. This may occur in contexts where previously successful compensatory strategies become inefficient due to incremental changes in the complexity of the individual's surrounding social environment (Livingston and Happé, 2017).

Evidences of compensatory processing were documented across a variety of cognitive processes in ASD. In general, it has been suggested that the typically intact declarative memory of individuals with ASD might be engaged in compensating impairments in their socio-cognitive functioning (Ullman & Pullman, 2015). In the remainder of this section, we will review literature which suggests that individuals with ASD compensate in some Theory of Mind tasks, thinking and reasoning tasks and category learning tasks.

4.1. Theory of Mind (henceforth, ToM): ToM refers to the intuitive understanding of others' and one's own mental states (White, Coniston, Rogers, & Frith, 2011). It is now widely accepted that individuals with ASD have a ToM deficit (Happé, 2015; Schuwerk, Vuori & Sodian 2015; Senju, Southgate, White, & Frith 2009; White, Frith, Rellecke, Al-Noor, & Gilbert, 2014). Nevertheless, the extent of ToM deficit detected in ASD varies as a function of the ToM task. Some, more able individuals with ASD pass Off-line ToM tasks, however they are unlikely to pass On-line ToM tasks (White, Coniston, Rogers, & Frith, 2011). Even though both On-line and Off-line measures of ToM evaluate the ability to appropriately attribute mental states, only the former allows for an evaluation in real time. In order to discuss how Off-line and On-line measures of ToM differently relate with compensatory processing, we will further present the findings of Abell, Happe, and Frith (2000).

Among other comparisons, Abell, Happe, and Frith (2000) evaluated 15 children with ASD in terms of their ToM abilities with both On-line and Off-line tasks. Concerning the offline measure of ToM, participants completed two first-order ("she thinks that…") false-belief tasks: The Sally-Ann test (Baron-Cohen et al., 1985) and Smarties test (Perner et al., 1989) and two second-order ("she thinks that he thinks that…") false-belief tasks: the Ice-Cream story (Perner & Wimmer, 1985) and Birthday

Puppy test (Sullivan et al., 1994). Concerning the online measure of ToM, participants viewed a pseudorandomized series of 10 video animations depicting the motion of two triangles. In 2 of the animations, the triangles were moving randomly on the screen (e.g., bouncing on the edges of the screen). In 4 of the animations, the triangles were physically responding to one another (e.g., synchronising movement as in a dance). Finally, 4 of the animations, "showed one character reacting to the other character's mental state. In one animation, one character tried to seduce and persuade the other to let it free." (Abell, Happe, & Frith, 2000, p. 5). After each animation, participants were asked "What happened in the cartoon?" Their responses were recorded and scored for appropriateness (see Abell, Happe, & Frith, 2000, p. 7). Authors found that even participants with ASD who passed both first and second-order false-belief tasks had marked impairments in appropriately describing the ToM animations. In sum, it seems that some individuals with ASD compensate their ToM impairments by relying on explicit processing of information. This compensatory processing strategy allows them to pass Off-line ToM measures (such as false-beliefs tasks) however, when tasks such as the Frith-Happe Animations (Abell, Happe, & Frith, 2000) do not allow for such compensatory processing strategy, their deficit in ToM becomes apparent.

4.2. Thinking and reasoning**:** According to the Dual Process Theory, human reasoning is composed of two distinct families of processes: Type One processing – which is not specific only to humans, is evolutionary old, unconstrained by working memory capacity, automatic, effortless, uncorrelated with general measures of intelligence, allowing intuitive judgements; and Type Two processing - which is specifically human, evolutionary recent, constrained by working memory capacity, controlled, effortful, correlated with general measures of intelligence, allowing abstract and hypothetical reasoning (for additional details, see Evans, 2003). Brosnan, Lewton, and Ashwin (2016) investigated if individuals with ASD have a tendency to rely on one type of processing more than the other. In order to achieve their goal, the authors compared 17 individuals with ASD with 18 individuals with TD on their performance on The Cognitive Reflection Task (CRT, Frederick, 2005). CRT is a 3 items performance questionnaire which assesses the human tendency to rely on Type One or Type Two processing. The questionnaire is designed in such manner that each question has both, potentially intuitive and deliberative answers. However, the intuitive answer is always wrong. Authors found that when compared with TDs, participants with ASD had a significantly higher performance on the CRT task therefore, they exerted a tendency to systematically rely on more deliberative and less intuitive reasoning. In sum, it seems that as opposed to individuals with TD, the default processing style of in individuals with ASD is characterised by a tendency to rely on explicit reasoning.

4.3. Category learning**:** Klinger and Dawson (2001) investigated if the deficit to integrate previously learned concepts to new situations - often reported in ASD research - is determined by an impairment in category formation. The authors compared 12 individuals with ASD and 12 individuals with TD on an explicit category learning task (which could be completed successfully with a rule-based approach) and an implicit category learning task (for which successful categorization was not permitted by a rule-based approach, but rather by automatically extracting prototypes from the encountered exemplars). Their results indicate that, when compared with individuals with TD, individuals with ASD demonstrated learning impairments when they completed the implicit category learning task and a sharp performance when they completed the explicit category learning task. For a paper describing the role of IL in category learning, see Goshke and Bolte (2007). In sum, consistent with literature reported earlier in this section, the results obtained by Klinger and Dawson (2001) also suggest that individuals with ASD compensate their deficit in automatic processing by adopting a rule-based, more deliberative style of reasoning.

In our opinion, the general form of compensatory processing which emerged from the studies reviewed in this section is that individuals with ASD compensate their impairments in automatic / intuitive processing by engaging in more effortful, deliberate processing. In the next section, we will discuss existing evidences which suggest that individuals with ASD engage such compensatory processing in IL tasks.

5. Are there evidences that individuals with ASD compensate in IL tasks?

As suggested by Foti et al. (2015), individuals with ASD seem to have a normal functioning of IL. However, behavioural studies offer only a quantitative, not qualitative measure of learning. The lack of between-groups differences in behaviourally measured performances cannot automatically exclude the use of a compensatory processing strategy or, a different processing style.

In this regard, Zwart et al. (2017) compared 20 individuals with ASD with 20 age, gender and IQ matched controls in terms of both their behavioural performance and electrical brain activity while performing the Serial Reaction Time Task. Participants in both groups were asked to respond via a key press to a sequence of arrows presented on the screen. Unknown to them, the arrows followed a complex sequence in 87.5% of all trials. Learning was indexed by the differences in the reaction times between the acquisition and deviant trials. The researchers recorded the electric brain activity while participants completed the acquisition phase. From a behavioural perspective, consistent with the conclusion of Foti et al. (2015), Zwart et al.'s (2017) results indicated no between-groups differences. However, the learning style of individuals with ASD was rather intentional - as it was associated with an increased P3 EEG component - and TD's learning was rather intuitive - as it was characterised by an increased N2b EEG component. In short, the authors argue that the typical performance of participants with ASD was sustained by a compensatory processing strategy – that is, an intentional style of learning, which is contrary to the learning style of individuals with TD.

Another study provides evidences consonant with the conclusion of Zwart et al. (2017) via a different methodological route. Specifically, Klinger et al. (2001, apud. Klinger, Klinger, & Pohlig, 2007) compared adolescents with TD and adolescents with ASD in terms of their performance on the Artificial Grammar Learning (AGL) task. Participants from both groups were exposed to a number of letter strings which, unbeknown to them, followed a complex artificial grammar. Subsequently, they were confronted with novel letter strings, out of which only half were consistent with the earlier artificial grammar. Participants underwent a classification phase, indicating for each string if it is grammatical or not. Learning was operationalised as an above-chance-accuracy in the classification phase. The results of Klinger et al. (2001) indicated that participants with TD had a 67% accuracy while participants with ASD had a 70% accuracy. The implicit nature of the learned knowledge was sustained by participant's inability to verbally describe the rules. With a general agreement between scientists, it is considered that - contrary to explicit learning - the functioning of IL is unrelated to intelligence (for details, see Reber, Walkenfeld, & Hernstadt, 1991). Importantly, Klinger et al. (2001) found that participants with ASD's performance in the AGL task was significantly related (r = 0.45) to their fluid intelligence (on the matrices task of the Kaufman Brief Intelligence Testm Kaufman & Kaufman, 1990) which was not the case for participants with TD (r = 0.13). In sum, consistent with earlier results, Klinger et al. (2001) suggest that the typical behavioural performance of individuals with ASD in the AGL task is associated with a potential compensatory processing strategy under the form of a more intentional style of learning.

The previous two studies discussed compensatory processing at a cognitive level. According to Livingston and Happé (2017), compensation can also be observed at a neural level. In this case, as opposed to non-compensators, individuals who compensate recruit different and/or additional neural pathways for completing a cognitive task. To this end, Müller, Cauich, Rubio, Mizuno, and Courchesne (2004) compared a group of 8 participants with ASD with 8 age, gender and IQ matched controls in terms of both their behavioural performances and neural correlates of implicit sequence learning. Participants completed a variation of the SRT task in a functional magnetic resonance imaging scanner. Contrary to the control group, participants with ASD showed less overall prefrontal activation in late phases of the learning task. Interestingly, the authors reported that individual with ASD were characterised by an enhanced activation in right pericentral and premotor cortex – which was a pattern not observed in the control group. Müller, Cauich, Rubio, Mizuno, and Courchesne (2004) provide empirical evidences suggesting that the typical behavioural performance observed in the ASD group was achieved by recruiting additional neuronal networks, which are not normally recruited by individuals with TD.

Finally, on the basis of the literature presented in this section, we will next discuss how the concept of compensatory processing can inform future research in the IL deficit in ASD hypothesis.

6. Directions for future research

On one hand, the majority of the available research examined the functioning of IL in ASD by employing standard, non-social paradigms. Studies exposed participants to stimuli such as: *circle shapes* (in Mostofsky, Goldberg, Landa, & Denckla, 2000); *blue dots* (in Müller, Cauich, Rubio, Mizuno, & Courchesne, 2004); *star shapes* (in Gordon & Stark, 2007); *black-and-white race cars* (in Travers, Klinger, Mussey, & Klinger, 2010); shapes of *L*s and *T*s (in Kourkoulou, Leekam, & Findlay, 2012), etc. On the other hand, individuals with ASD have marked deficits especially in the social domain. Crucially, IL is not a homogenous construct; subtle variations in the research paradigms reveal different facets of IL (for details, see Seger, 1997, 1998).

Here, we suggest that *a):* different cognitive mechanisms might be involved in the IL of social versus non-social information (thus, the extrapolation of results obtained with non-social paradigms to the functioning of IL in social contexts is, in our opinion, unadvisable) and *b):* considering the artificial nature of those tasks we suggest that the lack of behavioural evidences of an IL deficit in ASD might be generated by a successful compensatory processing strategy (an important question is whether or not such strategy will continue to be effective in more complex tasks that are more relevant for social functioning).

We speculate that the potential compensatory processing strategy which allowed participants with ASD to demonstrate intact performances in standard IL tasks (i,e,. an intentional learning style) will stop being effective in more socially relevant paradigms – especially considering that ASDs' face processing impairments are well documented in the literature. For instance, Dawson et al. (2002) argue that ASD is characterised by face recognition impairment that is manifest early in life. The comprehensive review of Weigelt, Koldewyn, and Kanwisher (2012) suggest that people with ASD perform worse than typical individuals when they have to remember or discriminate facial identities. Literature also provides consistent evidence regarding areas of the human face where individuals with ASD preferably allocate their attentional resources. More specifically, individuals with ASD are characterized by deficits in fixating the region of the eyes (Riby, Doherty-Sneddon, & Bruce, 2009; Dawson, Webb, & McPartland, 2005) and prolonged fixations in the mouth area (Neumann, Spezio, Piven, & Adolphs, 2006).

In sum, here we suggest that *a):* the ability to implicitly learn information on the basis of artificial stimuli might engage different processes than the ability to implicitly learn information on the basis of socially relevant stimuli (such as human expressions) and *b):* future research could test if the potential compensatory processing strategy (i.e., an intentional learning stile) which allowed participants to demonstrate intact performances in standard IL tasks will continue to be effective in IL paradigms that are more relevant for social functioning. For an example of a research paradigm (which could be used by future research to retest the IL deficit in ASD hypothesis) designed to induce IL of cognitive structures on the basis of human emotional facial expressions, see Jurchis, Costea, Opre (under review).

7. Conclusion

The hypothesis of an IL deficit in ASD assumes that the social deficits of individuals with ASD may be underlined by their impaired ability to implicitly learn regularities from the social realm. The majority of the available empirical studies testing this hypothesis report a lack of behavioural differences between individuals with ASD and normative controls. However, we discussed that in some cases, a typical behavioural functioning can be sub served by an atypical cognitive functioning. In this sense, we introduced the concept of compensatory processing, which occurs when a typical performance in a cognitive task is achieved through the recruitment of additional cognitive and/or neurobiological resources which are not recruited by individuals with TD).

After reviewing literature suggesting that individuals with ASD compensate in some ToM, Reasoning and Category learning tasks, we analysed evidences of compensatory processing in the available IL research. On the basis of the reviewed literature on the SRT and AGL tasks, it seems that individuals with ASD compensate in IL tasks by engaging in a rather intentional style of learning. As such strategy might be effective in simple, artificial tasks, we suggested that future research should test its effectiveness in more complex contexts that are more relevant for social functioning.

If future research will indeed detect that individuals with ASD have a deficit to implicitly learn socially relevant information then, this line of research will have several potential practical and research implications.

From a practical standpoint, it might inform the optimization of interventions for addressing this potentially malfunctioning process. For instance, in typical populations, it has been shown that IL is functioning optimally when individuals are in a subjectively defined non-optimal time of the day (Delpouve, Schmitz, & Peigneux, 2014). This could suggest a certain ordering of activities in the therapeutic sessions: starting with activities that require conscious thought (language learning, writing, etc.) when patients feel energised than, continuing with activities that require automatic processing (for instance, recognising emotions, etc.) when participants feel less energised. Additionally, this line of research, might inform caregivers and professionals about the importance that contextual factors – implicit learning - play in ASDs social functioning.

Finally, on a more speculative note, if confirmed, this line of investigation could have implications for future research and theory. For instance, it could lay the foundation to test if some currently distinct findings can be unified under a computational model of social cognition impairments in ASD. Specifically, we consider that it would be interesting to investigate the potential downstream effects that abnormal sensory processing of individuals with ASD (Crane, Goddard, & Pring, 2009; Marco, Hinkley, Hill, & Nagarajan, 2011) might have on the IL of socially relevant information and also, the potential downstream effects that an impaired ability to implicitly learn socially relevant information might have on ToM functioning in ASD.

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