Atrapado en la incertidumbre: El procesamiento predictivo y la inferencia activa en el comportamiento procrastinador del autismo.

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Resumen

Un fenómeno a menudo asociado con el autismo es un modo atípico de función ejecutiva, cuyas manifestaciones incluyen dificultad para iniciar tareas. En algunos casos, esto va acompañado de sentimientos de inercia y sensaciones que pueden describirse como inquietud y parálisis simultáneas. En consecuencia, la dificultad para iniciar las tareas puede dar lugar a la procrastinación, ya sea simplemente posponiendo el trabajo en la tarea objetivo o realizando otras tareas no relacionadas antes de dedicarse a la tarea objetivo. Curiosamente, sin embargo, también está documentado que, una vez iniciada una tarea, los autistas pueden centrarse en ella intensamente y durante periodos prolongados de tiempo, especialmente cuando les resulta interesante.

Este trabajo utiliza el procesamiento predictivo y la inferencia activa para modelar la relación entre la función ejecutiva, la procrastinación y la hiperfocalización en el autismo. Este modelo integra las causas conocidas y propuestas de los déficits en la función ejecutiva y el papel que desempeña el interés en la regulación de la atención y la motivación. El modelo propone que la procrastinación es el resultado de procesos diferenciales de minimización de errores de predicción, como la ponderación de estímulos sensoriales. Se discuten los vínculos con modelos propuestos previamente, como la coherencia central débil (CCC), y la teoría de los priores altos e inflexibles de los errores de predicción en el autismo (HIPPEA).

Palabras clave: autismo; procrastinación, coherencia central débil (CCC); priores altos e inflexibles de los errores de predicción en el autismo (HIPPEA).

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Stuck in uncertainty: A predictive processing/ active inference account of procrastination- like behaviour in autism.

Abstract

A phenomenon often associated with autism is an atypical mode of executive function, manifestations of which include difficulty in initiating tasks. In some cases, this is accompanied by feelings of inertia and sensations that can be described as simultaneous restlessness and paralysis. Consequently, difficulty in getting started on tasks can result in procrastination, either by simply postponing working on the target task or by performing other unrelated tasks before engaging in the target task. Interestingly, however, it is also documented that once a task has been started, autistic persons may focus on it intensely and for prolonged periods of time, especially when it is interesting to them.

This paper uses predictive processing and active inference to model the relationship between executive function, procrastination, and hyperfocus in autism. This model integrates the known and proposed causes of deficits in executive function and the role played by interest in attention regulation and motivation. The model proposes that procrastination is the outcome of differential prediction-error minimizing processes, such as weighting of sensory stimuli. Links to previously proposed models such as weak central coherence (WCC), and the theory of high, inflexible priors of prediction errors in autism (HIPPEA) are discussed.

Key Words: autism; procrastination, weak central coherence (WCC); high, inflexible priors of prediction errors in autism (HIPPEA).

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Coincé dans l'incertitude : Un traitement prédictif et une inférence active du comportement de procrastination dans l'autisme.

Résumé

Un phénomène souvent associé à l'autisme est un mode atypique des fonctions exécutives, dont les manifestations incluent une difficulté à initier des tâches. Dans certains cas, cela s'accompagne d'un sentiment d'inertie et de sensations qui peuvent être décrites comme une agitation et une paralysie simultanée. Par conséquent, la difficulté à commencer une tâche peut entraîner la procrastination, soit en reportant simplement le travail sur la tâche cible, soit en effectuant d'autres tâches sans rapport avec la tâche cible avant de s'y atteler. Il est toutefois intéressant de noter qu'une fois qu'une tâche a été entamée, les personnes autistes peuvent s'y consacrer intensément et pendant des périodes prolongées, en particulier lorsqu'elle est intéressante pour elles.

Cet article utilise le traitement prédictif et l'inférence active pour modéliser la relation entre la fonction exécutive, la procrastination et l'hyperfocalisation dans l'autisme. Ce modèle intègre les causes connues et proposées des déficits de la fonction exécutive et le rôle joué par l'intérêt dans la régulation de l'attention et la motivation. Le modèle propose que la procrastination soit le résultat de processus différentiels de minimisation des erreurs de prédiction, tels que la pondération des stimuli sensoriels. Les liens avec des modèles précédemment proposés, tels que la cohérence centrale faible (WCC), et la théorie des priors élevés et inflexibles des erreurs de prédiction dans l'autisme (HIPPEA) sont discutés.

Mots clés : autisme ; procrastination, faible cohérence centrale (WCC) ; prières élevées et inflexibles des erreurs de prédiction dans l'autisme (HIPPEA).

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Preso na incerteza: Uma explicação de processamento preditivo/inferência ativa do comportamento semelhante à procrastinação no autismo

Resumo:

Um fenómeno frequentemente associado ao autismo é um modo atípico de funcionamento executivo, cujas manifestações incluem a dificuldade em iniciar tarefas. Em alguns casos, esta dificuldade é acompanhada por sentimentos de inércia e sensações que podem ser descritas como inquietação e paralisia simultâneas. Consequentemente, a dificuldade em iniciar as tarefas pode resultar em procrastinação, quer adiando simplesmente o trabalho na tarefa-alvo, quer realizando outras tarefas não relacionadas antes de se dedicar à tarefa-alvo. Curiosamente, no entanto, também está documentado que, uma vez iniciada uma tarefa, as pessoas autistas podem concentrar-se nela intensamente e por períodos prolongados de tempo, especialmente quando é interessante para elas.

Este artigo utiliza o processamento preditivo e a inferência ativa para modelar a relação entre a função executiva, a procrastinação e a hiperfocalização no autismo. Este modelo integra as causas conhecidas e propostas de défices na função executiva e o papel desempenhado pelo interesse na regulação da atenção e motivação. O modelo propõe que a procrastinação é o resultado de processos diferenciais de minimização de erros de previsão, tais como a ponderação de estímulos sensoriais. São discutidas as ligações a modelos anteriormente propostos, como a coerência central fraca (CCI), e a teoria dos priores elevados e inflexíveis dos erros de previsão no autismo (HIPPEA).

Palavras chave: autismo; procrastinação, coerência central deficiente (WCC); orações elevadas e inflexíveis de erros de previsão no autismo (HIPPEA).

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1.   Introduction.

Procrastination has been defined as "the needless delay of things one intends to do" (Klingsieck 2013, 24). Its main characteristics are "the postponement of initiating or completing a commitment until the last minute, until after a predetermined deadline, or indefinitely" (Rozental and Carlbring 2014, 1489). A common phenomenon, procrastination is empirically documented to have a negative impact on well-being, stability, and psychological health. As such, there have been considerable efforts to address procrastination, for instance by developing strategies to combat, cope, or compensate for it. Procrastination can be contrasted with purposeful delay, wherein a task is postponed due to a need to prioritize other requirements, or because carrying it out at a later time would be more strategic (Klingsieck 2013). An act of delay qualifies as procrastination if it meets the following criteria (Klingsieck 2013, 25): voluntary, unnecessary, or irrational delay, whether overtly or covertly, of an act that the subject intends to start or complete, and which is necessary or important; furthermore, "the delay is achieved despite [awareness] of its potential negative consequences" and "is accompanied by subjective discomfort or other negative consequences."

The causes of procrastination have been attributed to issues regarding self-control, the need to prioritize or schedule tasks, selecting which among many tasks to accomplish, and perceptions or assumptions of what the task will be like (O'Donoghue and Rabin 2001).

However, as this paper argues, procrastination may also be related to sensory processing strategies and their influence on action selection. To test this hypothesis, the paper draws on procrastination in the context of autistic lived experience as a case study and develops a model of procrastination based on the related theories of predictive processing and active inference.

While procrastination is not unique to autistic individuals, this paper explores how certain neurocognitive features characteristic of autism may be linked to procrastination. Procrastination is construed as the outcome of how sensory processing styles associated with autism influence action selection. The model is thus concerned with developing positive accounts of how these sensory styles can

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lead to procrastination behaviours in autistic persons or others who exhibit the relevant processing patterns. As such, procrastination that is a result of other factors (e.g., lack of interest, perceived difficulty, ease, or lack of importance of the target task) that are not directly or exclusively linked to the cognitive and neurological features of autism are outside the scope of the model.

The reason for this scope is that certain phenomena are closely associated with, are more pronounced or frequent, or may pose significant challenges to functioning in autistic persons.

Among these are sensory overload, feelings of inertia or paralysis when starting or switching between tasks, demand avoidance, and insecurity when tasks or their outcomes are perceived as unpredictable). Interestingly, however, it is also documented that once a task has been started, autistic persons may focus on it intensely and for prolonged periods of time, especially when the task is interesting to them (F. Murray 2019; Dupuis et al. 2022). From a scientific perspective, it is intriguing to explore how these seemingly contradictory phenomena can coexist within the autistic lived experience and how they might be linked to divergent modes of sensory and cognitive processing. In a social context, these questions might be of particular relevance: Autistic persons still suffer from persistent social stigma and high levels of unemployment, which may be further exacerbated by difficulties in task completion and executive functioning (Doyle 2020). Therefore, gaining a better understanding of these phenomena may alleviate social pressures and help to develop tools and strategies to reduce procrastination-like patterns in members of the autistic community.

Autistic individuals exhibit differences in social behaviour, sensory perception, and cognition that set them apart from the neurotypical population (Baron-Cohen et al. 2001; American Psychiatric Association 2013; Fietz, Valencia, and Silani 2018). Historically and in popular media, autism has long been associated with young white males presenting with noticeable symptoms (e.g., avoiding eye contact, selective mutism, meltdowns) (Belcher and Maich 2014; Lyall et al. 2017). In 2013, the DSM-5 saw the incorporation of Asperger's Syndrome under the umbrella of Autism Spectrum Disorder (ASD), as well as a refinement of diagnostic criteria (American Psychiatric Association 2013). This has led to an increase in diagnoses in recent years, particularly in adults, females, and individuals with less severe symptoms or from

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racially diverse backgrounds (Lyall et al. 2017; Leedham et al. 2020). Current estimates assume a prevalence of 1.5% for ASD in the general population. These numbers are expected to rise with higher awareness among mental healthcare professionals, participation of autistic individuals within autism research, and more balance between genders and ethnicities as biased diagnostic criteria and stigmatization of the condition are gradually dismantled (Botha 2021; Hens, Robeyns, and Schaubroeck 2019; Lyall et al. 2017). Furthermore, the number of individuals recognizing themselves as part of the autistic community far exceeds those with a formal diagnosis of ASD (sensu DSM-5, American Psychiatric Association 2013), be it due to inaccessibility of mental health resources, limitations of diagnostic criteria, or the persistent social stigma tied to diagnosis (Lewis 2016). Within this paper, we therefore use the terms "autism" and "autistic" rather than "ASD" wherever applicable to fully encompass the population it pertains to, as well as identity-first language reflecting the majority preference of the autistic community (Taboas, Doepke, and Zimmerman 2023).

The paper proceeds as follows. Section 2 outlines autistic traits related to procrastination. Section 3 presents an overview of predictive processing and active inference. Section 4 develops the model by accounting for different types of procrastination and how they may be related to sensory processing and executive function in autism. Section 5 concludes the paper.

2.   Autistic traits contributing to procrastination-like behaviours.

> Executive function and social adjustment challenges make demands on our processing
> resource and interfere with our doing the things we do most sweetly (D. Murray 2018,
> 2).

Building on previous research on atypical patterns of predictive processing and executive functioning, the autistic lived experience represents a compelling case study to examine the mutual interactions of these phenomena. In the following list, we highlight five neurocognitive features commonly associated with autism that may contribute to increased procrastination-like activities:

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i.   Previous studies on executive function—i.e., the regulation of goal-directed, future-oriented, higher-order cognitive processes—suggest a high variability of these capacities within the autistic population (Johnston et al. 2019; Demetriou, DeMayo, and Guastella 2019). While not all aspects of executive functioning are generally affected, members of the autistic community frequently report difficulties initiating or switching between tasks. Often termed "autistic inertia" (F. Murray 2019), this struggle to shift from a currently ongoing task to a new one, or transition from periods of inactivity to activity and vice versa is certainly linked to procrastination-like behavioural patterns in autistic individuals.

ii.   Sensory processing and the weighting of sensory cues are frequently atypical and highly context dependent in autistic individuals (Palmer, Lawson, and Hohwy 2017): High sensitivity to certain sensory inputs in a complex environment may create sensory overload and hamper focus on or choice of an individual task (Pellicano and Burr 2012). On the other hand, reduced sensitivity to environmental or interoceptive stimuli or immersion in a prior task can keep an individual from processing the necessary cues to engage in a new task. Especially with strong monotropic interests or phases of hyperfocus, switching from a task of current interest to a different one may be extremely difficult (D. Murray 2018).

iii.   The theory of high, inflexible priors of prediction errors in autism (HIPPEA) describes common autistic traits such as preference for sameness and atypical sensory sensitivities from the perspective of predictive processing (Constant et al. 2020). In this framework, sensory and social avoidance, reliance on routines, and reduction of novel stimuli serve to construct a predictable sensory niche for the autistic person. For executive functioning, this may mean that both the environment and the consequences of one's own actions are experienced as more unreliable (Pellicano & Burr 2012, Lawson et al. 2014); the ability to choose the appropriate task for the desired outcome may thus be impaired. On the other hand, this tendency toward inflexible routines can also be beneficial, if recurring tasks are incorporated into them and supported by environmental and social structures.

iv.   So-called "weak central coherence" (WCC) has long been thought of as one of the defining characteristics of autism. This term refers to the tendency of autistic individuals to focus intensely on small details or restricted sets of interests, rather than the greater context (American

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Psychiatric Association 2013). As studies on WCC have yielded mixed results, the question remains whether WCC should be considered a cognitive deficit or an autistic strength. A recently published review article states: "The selected studies lend evidence to the notion of amplified localized perception rather than deficient global perception. In other words, WCC may represent a superiority in "local processing" rather than a deficit in global processing" (Scher and Shyman 2019, 141). Thus, the traditional expert view of WCC as an obstacle for cognitive flexibility and "seeing the bigger picture" may currently be shifting towards a more positive interpretation. In fact, autistic individuals may largely benefit from their focusing abilities, in-depth knowledge about specific subjects, and attention to detail (Scher and Shyman 2019; Grandin and Panek 2013; Russell et al. 2019). However, when facing a task to be done, a high awareness of individual steps and small sub-tasks can create overwhelm and delay task initiation (Demetriou, DeMayo, and Guastella 2019). Incorporating tasks into larger modules in the course of routines or traditions may be beneficial in this case.

v. Autism frequently co-occurs with other psychological and physical conditions that may likewise impair task selection and execution but should be considered separately from the framework proposed herein. Examples include AD(H)D, where executive dysfunction is often linked to distractibility, forgetfulness, or difficulty in planning (Silverstein et al. 2020); generalized or social anxiety disorders may lead to perfectionism or fear of not executing the task in a satisfactory manner (Andreae, Durrant, and Kyffin 2019); extreme demand avoidance (EDA) is strongly linked to both anxiety and autism and can contribute to strong resistance when faced with everyday tasks (White et al. 2023); likewise, depression may also present as inertia and difficulty in task execution (Nuño et al. 2021). Relevant physical conditions may include dyspraxia, leading to difficulty in the motor coordination necessary for task execution (Zampella et al. 2021), or connective tissue disorders (e.g., Ehlers-Danlos Syndrome), which may cause difficulties due to pain and limited energy (Casanova et al. 2020).

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3.   Predictive processing and active inference.

Predictive processing and active inference are related theories that construe the nervous system as a "hypothesis tester" (Hohwy 2013; Clark 2016). Lacking direct access to states external to the organism, the nervous system is dependent on signals received from the sensory array for its information about the world. Exteroceptive signals supply information about the external features of the world, while interoceptive signals register the internal effects of the different aspects of the world on the organism. From these signals, the nervous system must infer or reconstruct the causal matrix of the world (Clark 2013), in the process generating hypotheses about the likely causes of the sensory information it receives. While some features of the generative model are generalizable within a species, others vary considerably across individual phenotypes. The generative model is influenced by multiple factors, including individual biological and neurological makeup, cognitive styles, behavioural tendencies, life experience, and ecological situatedness.

The mechanism behind the hypothesis testing processes, which are implemented through cognition and action, is known as the generative model. The generative model has been defined as an internal model "implicit in [an organism's] phenotype" (Friston, Kilner, and Harrison 2006, 78) that "[encodes] the statistical structure of the local environment" (Ramstead et al. 2019, 190). To accomplish this, the generative model draws on incoming sensory signals as well as stored information known as priors. Some priors can be phenotypically encoded, while others are acquired through learning and experience (Ramstead et al. 2019). Because the hypotheses formulated by the generative model are its means of gaining information about the world and are the foundation for the organism's engagement with the external environment, it is crucial that they constantly be tested for accuracy. Accurate hypotheses identify correct or probable causal relationships, and therefore reliably reconstruct the world's causal matrix.

One way the generative model's accuracy is tested is through another of its main functions, namely formulating predictions. Predictions can be understood as expectations of the conditions (or more precisely, the sensory consequences of these conditions) the organism is likely to experience in the

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proximal or distant future. They draw on information made available by priors and hypotheses. Predictions are transmitted downstream, and are met by bottom-up, real-time sensory signals. When the sensory signals match the salient aspects of the prediction, then the prediction is fulfilled and the underlying hypotheses are confirmed. On the other hand, mismatch between the prediction and occurrent sensory signals produces prediction error, or signals that encode this difference. The prediction error signal is sent upstream, where it is used to update the generative model's hypotheses and the prediction. The modified prediction is then transmitted back downstream where it is once again compared with the actual sensory signals. This process is repeated until the prediction and the occurrent sensory information adequately match. Short-term implementation of this strategy is unpacked as perception, while when it is carried over the long-term it qualifies as learning (Scholz et al. 2022).

However, updating the generative model via perceptual processes is sometimes insufficient to minimize prediction error. Instead, a more involved approach such as action is needed. Prediction error via action involves reconfiguring the environment to make it conform with the prediction, thereby fulfilling rather than correcting predictions (Adams, Shipp, and Friston 2013). The role of action in prediction error minimization has been developed in the theory of active inference, which is considered the "standard approach to action in predictive processing" (Vance 2017, 1). In specifying the sensory consequences of anticipated states, the generative model likewise prescribes action policies or sets of movements that are likely to be the most effective at minimizing prediction error, by bringing the environment into a configuration that will match the prediction (Friston et al. 2015). These action policies, in turn, contain information about how the motor system should be activated to implement the necessary movements.

When a prescribed action policy is not yet implemented, error signals are generated because the effectors are in different states from those specified by the action policy. Once these error signals gain sufficient weighting or signal salience, they activate the motor system, thus setting the action policy into motion (Adams, Shipp, and Friston 2013; Vance 2017). As the effectors perform the necessary movements, sensory signals begin to match the prediction, thereby fulfilling it and reducing error signals. However, like its perceptual counterpart, the initial implementation of the action policy may not

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successfully minimize prediction error. As such, the movements (or aspects of them) must be repeated until prediction error is sufficiently reduced.

Since predictions are the basis of how the organism engages with the environment, it is crucial that they are sufficiently accurate (as will be discussed shortly). Accurate predictions allow the organism to anticipate the conditions it is likely to find itself in, and therefore enable it to formulate appropriate responses. This increases the likelihood of adaptive cognitive and behavioural responses. In contrast, inaccurate predictions can place the organism in a state of surprisal, wherein predictions are not matched by the actual conditions, thereby generating prediction error. Because the actual conditions differ from anticipated ones, the organism is at higher risk of inappropriate or maladaptive responses, as well as discomfort, injury, or even death. Furthermore, the effects of surprisal can be cumulative. An organism that frequently experiences surprisal over the course of its life is more susceptible to disruption to physiological, cognitive, behavioural, or psychological homeostasis. For this reason, prediction error and surprisal must be kept to a workable minimum (realistically, it is difficult to fully avoid these states over an entire lifespan). Once again, it must be noted that differences in individual phenotype entail that states that are surprising vary from one organism to another.

Now, while the prediction must be accurate, the degree of its precision is also important: it must be able to accommodate a margin of mismatch without compromising its reliability. If the prediction is too "promiscuous," it can be matched by too many signals for it to be genuinely informative. Let us take as an example a beginning (and tone-deaf) violin player practicing intonation without the help of a tuner. A prediction is formulated that when she plays a certain string, the note A will sound. However, the prediction does not specify exactly what the A should sound like, e.g., at a frequency of 440 Hz. As such, so long as the sound is "approximately this high," the violinist is unable to tell whether what she is playing is too low, too high—or whether it is actually even close to an A. (In contrast, a professional musician with better pitch memory can have a prediction that when A is played, it will sound a particular way, and that way only.) Thus, without an external or correctly memorized pitch reference, the sound made by the string—so long as it is high or low enough—will confirm the prediction that it is an A. Consequently, even if the A is off-pitch, no error signals will arise that can be used to update the generative model's

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information of what A should sound like. On the other hand, if the generative model is overfitted, too many parameters of the prediction need to be matched and too closely, so that the prediction error minimization process is repeated excessively (Hohwy 2019). Here, highly specific sets of sensory signals are required to fulfill the prediction, and even a slight deviation can result in prediction error. If the persisting error signal remains sufficiently salient, repeated selection of the action policy manifesting as perseverative behaviours can occur (Spee et al. 2022).

4. Modelling procrastination

4.1 A thousand and one stimuli

The first type of procrastination, difficulty in initiating the target task, is accounted for by drawing on existing models of predictive processing outlined below, and combined with the theory of affordances as it has been incorporated by active inference.

Under the aberrant precision account of autism (Pellicano and Burr 2012; Lawson, Mathys, and Rees 2017; Palmer, Lawson, and Hohwy 2017), individuals are assumed to form so- called hypo-priors that may lead to more accurate perception on the one hand, and reduced reliance on prior experiences on the other. Common sensory and social features of the autistic experience such as repetitive and self-regulating behaviours (stimming) have been proposed as means to reduce environmental uncertainty within this framework. Similarly, the hypothesis of high, inflexible precision of prediction errors in autism (HIPPEA) provides an ecologically informed account of the social and non-social aspects of autism (Constant et al. 2020). HIPPEA links autistic traits (e.g., sensory and social avoidance, reliance on routines, and reduction of novel stimuli) to differently "tuned" neurocognitive mechanisms. These may lead to atypically high precision assigned to bottom-up prediction errors and further to overfitted models that will not readily generalize to new inputs. The HIPPEA framework thereby describes common autistic traits as means to construct a predictable niche for the autistic person in an otherwise overwhelming and unpredictable environment.

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Being coupled to the environment, the subject is immersed in sensory information, which in turn influences engagement with the world (Friston et al. 2014). This engagement includes observations of the properties of the surroundings, but also of the opportunities for action, also known as affordances, that they present. First proposed by J. J. Gibson (1979), affordances are possibilities for action associated with an object or stimulus. Gibson writes that "the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (James Jerome Gibson 1986, 127). More recently, it has been proposed that "we are also sensitive to affordances for mental actions such as attending, imagining and counting" (McClelland 2020, 401). Here, "subjects perceive opportunities to perform a mental action and their doing so leads, under the right conditions, to the automatic preparation of that action" (McClelland 2020, 401). Traditional views on affordances hold that they are perceived by the subject as an aspect of the stimulus being attended to; it has also been claimed that perception of affordances is an innate component of sensory processes. Within active inference, affordances are viewed as integrated within an action policy, such that they are "[attributes] of the plan or course of action" (Friston 2022, 217), in that they "encode object-and-situation-specific action policies" (Scholz et al. 2022, 2). It has also been proposed that affordances influence action selection, as they reflect "beliefs about the consequences of action" (Friston 2022, 216), thereby helping to formulate predictions about the conditions the subject can expect to encounter.

By incorporating affordances into predictive processing and active inference, the model can explain how the sensory processing styles associated with autism can be linked to the behavioural substrates of procrastination. Recall that perception of stimuli is vital to formulating and selecting action policies. In accordance with previously postulated models (e.g., WCC, HIPPEA; see above) autistic individuals frequently report a broad range of stimuli being perceived as salient, thus resulting not only in competing signal weight but also in a high volume of perceived affordances. This heightened focus on details rather than the "big picture" can in turn lead to sensory overload and the tendency to seek out less stimulating, more predictable tasks and environments (Constant et al. 2020; Pellicano and Burr 2012; Palmer, Lawson, and Hohwy 2017). When stimuli are bound together as part of a single context, the affordances— sensory and mental—registered pertain to the overall context. In contrast, when the stimuli are encoded as distinct from each other, what may be perceived are affordances relates to the individual

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stimuli. The latter would result in considerably more affordances being encoded than the former. By registering numerous possibilities for action In the environment, the generative model then formulates corresponding predictions of the sensory consequences of acting on these distinct possibilities. Since there is a profusion of possibilities, the volume of predictions will be correspondingly high. So long as these predictions are unfulfilled, they will continue to generate prediction error.

Under active inference, the most effective strategy for minimizing prediction error would be to implement an action policy that would realize certain possibilities. However, the comparable salience of the stimuli may hinder this, as the "potential actions compete against each other for further processing, while information is collected to bias this competition until a single response is selected" (Cisek 2007, 1585). As such, the various aspects of "external sensory information about objects in the world and…internal information about the current behavioural needs" (Cisek 2007, 1585) that influence action selection may be assigned comparable importance. It thus becomes difficult for the generative model to determine which action policy will be most successful at reducing prediction error, or at prioritizing which policy to implement before the others. Consequently, no single action policy has sufficient weight to activate the motor system to implement the action (see Adams, Shipp, and Friston 2013). The outcome is thus inaction, which may sometimes be accompanied by or experienced as a sense of inertia, dread, or paralysis (F. Murray 2019). This scenario, wherein the action policy encoding the target task fails to be implemented, can manifest as difficulty initiating the target task.

4.2   If i''s important, it can wait.

The second form of procrastination is delay in beginning the target task due to preoccupation with or intense focus on a peripheral task, especially when the latter is deemed interesting or enjoyable (D. Murray 2018). An interesting task is registered as highly salient, leading to the action policies associated with it being repeatedly selected. An enjoyable task generates predictions of positive or pleasurable sensations. If the task has not yet been begun, prediction error is generated and can only be quashed by implementing the relevant action policy. On the other hand, if the task is already underway, the predictions are confirmed by the incoming sensations associated with enjoyment. This can be reinforced by other

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factors, such as responses of the dopaminergic system, positive affective signals, or reward signals, thereby adding more weight to the relevant action policy (Spee et al. 2022). Furthermore, progress in the task may bring about incremental reconfigurations of the environment (for instance the gradual change in the shape of a Lego structure the subject is building), which in turn presents new affordances and stimulates the formulation of new predictions. Importantly, because of the incremental nature of the changes being made, these predictions encode aspects of the world that are familiar (e.g., what the structure presently looks like) and others that are novel (e.g., what the structure will look like when a block is added). The drive to test these predictions thus contributes to the reselection of the action policy.

The result is continuous work on the task, so long as there is no significant change in sensory signals that could require a shift in action policy selection. Importantly, this should not be confused with continuous reselection of an action policy due to overly precise predictions that are difficult to fulfil, such as that associated with compulsive behaviours (Friston 2022). In compulsive behaviours, an overfitted generative model results in unusual difficulty in matching the prediction through action and thus quashing prediction error. The action policy is thus reselected over and over again in attempts to generate sensory signals that can match the prediction. Compulsive action reselection can be differentiated from prolonged engagement in a task enjoyment as such: the former is the outcome of repeated unsuccessful attempts to minimize prediction error, while the latter can be attributed to increased weighting on the signals associated with the task.

Combining the account just proposed with accounts of context-dependent sensory processing in autism (e.g., Constant et al. 2020) may account for delayed shifting to the target task due to preoccupation with another, wherein certain sets of stimuli have significantly more salience than others. Within the autistic experience, this can manifest as so-called hyperfocus, i.e., a flow-like state involving increased attention on a specific object or task, often over prolonged periods of time and to the exclusion of all other tasks or even physiological needs (Johnston et al. 2019; Scher and Shyman 2019; Dupuis et al. 2022). While such states are not exclusive to autism, and can be beneficial to the subject in certain contexts, they may also lead to inflexible behavioural patterns of fixation or perseveration that can be detrimental to task execution (Spee et al. 2022; Dupuis et al. 2022). In addition to continuous reselection of a particular action

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policy, a consequence of this selective focus can be suppression or insufficient weighting assigned to sensory or cognitive cues pertaining to other states—such as those regarding another task in need of completion. As a result, the action policies that would implement behaviour in response to these cues fail to become salient enough to access the motor system. However, the weighting of target task-related cues and consequently action policies may increase at a later point due to changes in endogenous or exogenous conditions. For instance, behavioural or cognitive techniques can be employed to draw focus away from the task being performed. An example would be getting up and moving around after sitting at a computer for hours on end, using a timer to take breaks at regular intervals, or simply getting tired. By introducing or drawing attention to different stimuli, the continuous reselection of the original action policy can be interrupted. Likewise, internal sensations such as sleepiness or hunger– which in autistic persons may be temporarily overridden by hyperfocus—can start to compete with task-related ones. Consequently, new predictions based on the properties of these sensations may arise. As such, different behaviours are required to quash the resulting prediction error. A new action policy associated with the more recent signals is thus formulated, is assigned greater priority, and thus is able to activate the motor system. By supplanting the former action policy, a shift in behaviour is thus brought about.

A change in external conditions can also contribute to selection of a new action policy. Perhaps the most familiar example is a fast-approaching deadline. The increased awareness of an impending deadline has been known to induce unpleasant physical and cognitive sensations of discomfort, anxiety, or fear in some subjects. The uncomfortable nature of these states has been interpreted by some scholars as disruption to homeostasis (see Friston 2022) and must thus be addressed to restore more stable conditions. This discomfort can be traced to the prediction error generated by predictions related to the unfulfilled target task failing to be quashed due to the subject's inaction.

The free energy principle (FEP), a theory closely related to predictive processing and active inference, claims that living organisms are characterized by the "hard-wired" tendency towards maintaining homeostasis (Friston, Kilner, and Harrison 2006; Ramstead et al. 2019; Friston 2013). According to the FEP, an organism has a repertoire of unsurprising states, which are encoded in the generative model as likely to be encountered over its lifespan (Friston, Kilner, and Harrison 2006;

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Ramstead et al. 2019; Hesp et al. 2019). This repertoire is determined partly by the organism's phenotype, and partly by individual experiences over the course of its life. For instance, for an octopus being surrounded by water would be unsurprising, but an ant that finds itself immersed in a watery environment would experience immense surprisal. To maintain homeostasis, an organism must ensure that it remains within its repertoire of familiar states as much as possible. The familiarity of these states enables the organism to reliably predict future outcomes that it may encounter, and thus prepare for them. In contrast, states outside this repertoire are surprising, so the organism is less effective at anticipating future conditions. This can lead to inaccurate predictions, which in addition to generating prediction error places the organism at risk of being unable to successfully navigate the environment. Consequently, surprisal increases the organism's susceptibility to disruption to homeostasis—or what the FEP terms phase transitions—in the form of discomfort, maladaptive responses, injury, or even death. Furthermore, this risk is cumulative: the more the organism finds itself in surprising states, the higher its chances of undergoing phase transitions. As such, it is in the organism's best interest to remain within its repertoire of predictable conditions, or as the FEP puts it, "avoid surprises and you will last longer" (Friston, Thornton, and Clark 2012, 2).

Homeostasis can be maintained through behavioural strategies, the prime example of which is selective exposure. Here, the organism limits itself to circumstances that are familiar, thus reducing the chances of encountering surprising situations that generate high levels of prediction error and increase the risk of phase transitions. Nevertheless, selective exposure may not always be possible, or may not always be effective at precluding surprisal. For instance, stress induced by an urgent, inescapable task with grave consequences if left uncompleted cannot be eliminated by hiding away on a pleasant tropical island until the deadline passes. Instead, the most effective means of restoring homeostasis is to select the action policy that will produce the signals needed to match the task-related predictions—in other words, by performing the task itself. Thus, following the FEP and active inference, prediction error and signals that homeostasis is disrupted are what drive the switch from the peripheral to the target task. However, these signals may take time to acquire the salience needed to implement the action policy, thereby accounting for the delay in moving from one task to another.

4.3   The least among evils.

The third form of procrastination is engaging in other peripheral tasks instead of starting on the target task. This often takes place when there are multiple tasks with varying degrees of importance available to the subject to choose from (O'Donoghue and Rabin 2001). The target task is the most important or urgent or has the most severe repercussions if left uncompleted, while the peripheral tasks are of secondary importance or urgency in comparison to the target task.

While these behavioural patterns are by no means exclusive to autism, autistic modes of cognition and perception may contribute to this type of procrastination. As listed above, extreme demand avoidance can lead to choosing less important peripheral tasks instead of the most urgent one that is therefore tied to higher social expectations and pressures (White et al. 2023).

Similarly, autistic persons' potential for high focus on a task of particular interest can make it difficult to switch to a less satisfying or interesting activity even if its completion is objectively more important (D. Murray 2018). Finally, as mentioned in the context of the HIPPEA model, autistic processing often entails a preference for more familiar and easily predictable situations when compared to the neurotypical population (Constant et al. 2020; Pellicano and Burr 2012; Palmer, Lawson, and Hohwy 2017). In accordance with the aberrant precision account outlined above, autistic individuals may perceive tasks as novel or unpredictable, even if only slight changes are made to prior experiences with similar activities. Thus, when faced with a choice between a more pressing task with unclear processes and/or outcomes and one or several less urgent but more familiar tasks, the autistic person will be inclined to choose the latter.

Since the typical human nervous system is able to anticipate the consequences of actions (Friston 2022), it can be inferred that awareness of the target task can give rise to predictions of what performing it will be like. Based on its prior beliefs about what the target task involves, the generative model formulates predictions of the sensory states that will arise when the action policy encoding the target task is implemented. Following the claims of the FEP, this can influence the generative model to 1) select action

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policies that lead to behaviours that will not disrupt homeostasis, and 2) to not select the action policy associated with the task (Friston et al. 2015). It is proposed that procrastination in the present form results from a combination of the two.

When the task is perceived with negative valence, for instance as tedious, boring, difficult, or unfamiliar, this can lead the generative model to anticipate states disruptive to homeostasis. As such, the generative model avoids selecting the target task's action policy for as long as possible in order to maintain immediate homeostasis. Furthermore, when the target task is unfamiliar, it can generate what the FEP calls as expected surprisal. This somewhat paradoxical term refers to predictions that, as the outcome of certain behaviours or exposure to certain states, one will encounter conditions that cannot be reliably predicted. This can reinforce the target task's being encoded as disruptive to homeostasis. Nevertheless, when the signals associated with the target task reach a certain level of salience (see section 4.2), a threshold is reached when the only way to quash the error signals is to initiate the task. In other words, non- selection of the target task is effective at maintaining homeostasis in the short term, i.e., by keeping the subject from experiencing the unpleasant signals predicted to accompany the target task. However, this solution is only temporary: when compounded by additional signals, such as increasing awareness of the deadline, anxiety, or social pressures, then avoidance ceases to be effective, and actually accomplishing the task becomes the sole way to minimize the error signals and thus return to homeostatic states.

The generative model can likewise"pred'ct the sensory consequences of the peripheral tasks, assuming they are familiar. Some peripheral tasks might be enjoyable, in which case they are positively selected because they are predicted to have positively-valenced consequences (see section 4.2). In contrast, other peripheral tasks might seem unpleasant. However, when compared to the target task, their anticipated consequences are less unfavourable, and thus less disruptive to homeostasis. For instance, while cleaning may be registered as tedious, it is not as tiresome as preparing the administrative sections of yet another grant application. As such, when the generative model is presented with the options to either clean the house or get started on the grant, the task predicted to be less disagreeable is selected. In other words, the peripheral task is selected not so much because it is encoded as pleasurable, but because

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engaging in it invariably delays or prevents selection of the target task, in the process postponing the subject's inevitable exposure to anticipated unpleasantness.

5. Conclusion.

Within this paper, we examined three forms of procrastination-like behaviours commonly experienced by autistic individuals. Drawing from existing models such as HIPPEA, the FEP, and the theory of affordances, we show how all three—i.e., delay in task initiation, preoccupation with a more salient task, and engagement in multiple peripheral tasks—may be better understood through the lens of predictive processing and active inference. We propose that procrastination in autism is the outcome of atypical prediction-error minimizing processes, such as differential weighting of sensory stimuli and avoidance of uncertainty.

While this study may lay the groundwork in the shape of a theoretical exploration of the matter, we hope to inspire future work that may benefit autistic and other neurodivergent individuals struggling with the social stigma of procrastination and inertia in their everyday lives. Developing tools to better manage these patterns, e.g., incorporating tasks into larger modules in the course of routines, traditions and external structure may be beneficial and help to alleviate persistent stigma and negative social outcomes. However, autism frequently co-occurs with other psychological and physical conditions such as AD(H)D, anxiety, depression, and physical disabilities, that may likewise influence modes of task selection and execution but should be considered separately from the framework proposed herein.

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