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BEYOND BIAS
INDIVIDUAL AND SOCIAL ASPECTS OF PERFORMANCE

PhD thesis

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LIST OF ABBREVATIONS

CBTT	Corsi Block Tapping Test
CI	Confidence Interval
DA	Decisional Awareness
DK	Dunning-Kruger
FA	False Alarm
GB	Boomer Generation (born between 1946-64)
GM	Millennial Generation (born between 1965-80)
GX	Generation X (born between 1981-96)
GY	Generation Y (born between 1997-2012)
IMMMT	Inoue-Matsuzawa Masked Memory Task
L	Learning phase
MM	Metamemory
mRNA	Messenger Ribo-Nucleic Acid
P	Performance
PVS	Post-Vaccination Syndrome
RT	Reaction Time
SA	Self-Assessment
SAB	Self-Assessment Bias
SD	Standard Deviation
T	Test phase
ToM	Theory of Mind

1. INTRODUCTION

The quest to comprehend ourselves and the world around us has been on the minds of scholars since the dawn of humanity: from the ancient Greek philosophers through the Empiricists who disputed Descartes' *fundamentum absolutum inconcossum* to Freud's suspicion-infused mythology, to become an *aporia* of a sort, and a cornerstone of the birth of psychology.

The dispute between the certainty of the Cartesian *ego cogitans* and the psychoanalysts' skepticism picturing man as a slave of the partially conscious unconscious has since been repeatedely reopened and reframed from the ill fated behaviorist Watson's *tabula rasa*, through Rogers's person-centered apporach and Maslow's inherently benevolent, well-intentioned and developmentally flexible individual to Bruner's Gordian stroke of highlighting personal responsibility while integrating innate and acquired talents into a single framework [1], all contribute to the argument.

Can all these perspectives be correct, even though they appear to contradict one another? How can the elusively fascinating nature of consciousness be captured emprically, and how can an individual's capacity for self-knowledge about their own knowledge be assessed if it fundamentally relies on subjective experiences, hence the absence of absolute reality?

Given the complexity of the issue, substantial reduction is required for a viable solution. Without advocating for any particular theory, Flavell demonstrated through recall-based memory performance that individuals have access to their knowledge about their own knowledge [2] and directed the explanation towards the behavioural scientific exploration – finally leaving less room for educated guessing and other phyilosophical debates.

Self-reflection and self-assessment play a crucial role in daily life, influencing personal development, decision-making, and interpersonal relationships. Engaging in reflective practices fosters self-awareness, allowing individuals to recognize their cognitive biases, emotional responses, and habitual patterns of thought, hence contributes to greater adaptability and resilience, enhancing one's ability to navigate complex personal and social situations. Social cognition emerges from the dynamic interaction of metacognition – introspective awareness of knowledge and uncertainty – and theory of mind (ToM) –

the inference of others' beliefs, intentions, and emotions – develops in tandem with metacognitive capacity, with both relying on overlapping executive resources and medial prefrontal cortex engagement [3,4]. Emotion recognition, particularly via facial expressions, requires accurate decoding of facial affect and it is deeply influenced by ToM abilities, especially in ambiguous or context-rich scenarios [5], while cognitive empathy strongly overlaps with ToM processes. Affective empathy on the other hand was found to be increasingly tied to embodied mechanisms, such as facial mimicry [6]. Mimicry is thought to ground emotion recognition in sensorimotor resonance; yet meta-analyses show that its influence is modulated by attention, individual empathic traits, and metacognitive evaluation of the perceptual input [7].

In professional settings, self-assessment is integral to leadership, productivity, and continuous improvement, where decisional awareness – the subjective sense of knowing whether a choice was correct – has been linked to and ubiquitous and domain-general factor: the subjective ease of cognitive operations, fluency, acts as an internal cue, feeding into metacognitive systems to shape decisional awareness across perception, memory, reasoning, and social inference. [8,9]. At the neural level, fluency is reflected in mid-frontal theta and posterior alpha desynchronization, correlating with both ease of processing and confidence formation [10]. The ventromedial prefrontal cortex (vmPFC), a hub for valuation and metacognitive judgment, integrates fluency cues with decisional outputs, suggesting a common computational currency for self-evaluation [11]. Illusory fluency, however, as induced by repetition, framing, or semantic priming, can result in impaired decisional awareness by inflating confidence without a corresponding improvement in performance [12].

From a psychological perspective, self-reflection and self-assessment are foundational to mental health. Therapeutic approaches such as cognitive-behavioral therapy (CBT), neurolinguistic therapy and psychoterapy (NLT, NLPT) and mindfulness-based interventions emphasize the importance of recognizing and restructuring thought patterns, the very processes that enhance emotional regulation and contribute to overall well-being. [13]

As thoughts and emotions are similarly stimulating as any other event on the horizon, metacognition is no other than the eye of the mind that observes itself and creates the experience of self, hence allowing individuals to evaluate their cognitive strategies, recognize gaps in their knowledge, and refine their approaches to information processing. Additionally, empathy – as a special form of metacognition – closely links cognition with affection, facilitates collaboration, interpersonal connections and social cohesion [14].

Testing basic cognition – contrary to higher level functions such as general intelligence – presents a unique opportunity to measure performance regardless of level of education, while opens a window of opportunity to understand how deeply rooted self-assessment – a suspiciously general metacognitive function that assesses any target within its reach to an individually different degree – can be, and whether and how does it relate to empathy.

To explore the relations between metacognitive abilities and empathy, first we had to design the experiment that proves self-assessment is a cognitive capacity-dependent metacognitive function and not a statistical artefact [15]. In the middle of the second data collection in 2020, COVID-19 hit the world, so we had to test again after the pandemic to understand our results better [16], and concluded "that self-assessment bias interplays in subconscious communication – the expression, control and recognition of facial emotions, especially – with empathetic skills and manipulation" [17].

1.1. Performance, self-assessment and other details

Self-assessment bias reported by Dunning & Kruger 25 years ago [18] sparked intense debate right away [19,20] and often found itself in the crosshairs of mathematical modelling, mostly to challenge [21,22] and sometimes even depreciate [23] the otherwise obvious, capacity-dependent nature of cognitive biases based on marginal distortion effects and better-than-average heuristics. Scientists, however, regularly came to the conclusion that performance and self-assessment are proportional [24,25,26], linked the phenomena with almost every relevant aspect of human behaviour from spatial cognition to occupational psychology [27,28,29,30,31].

Although metacognitive abilities are not entirely human-specific [32], metacognition, however, from metamemory or knowing what we know [2,33], defines complex cognitive – e.g. metacognitive judgements [34], theory of mind [35], reasoning [36] – and affective abilities – eg. empathy [37], motivation [38,39] – that are essential in human social interactions [40], and are entirely capacity dependent [41,42].

Metacognitive effectiveness plays an inevitable role in mental health [43], and organic or functional impairments in neural correlates, such as the anterior and posterior cingulate cortex, insula, precuneus, superior temporal gyrus, inferior parietal lobe, ventromedial prefrontal cortex, and dorsolateral and frontopolar cortex [44] – in which Brodmann area 9/10 centrally contribute in organising the introspective process based on grey matter differences and blood-oxygen level dependent (BOLD) signal analysis in a special form of thought monitoring: lucid dreaming [45] – characterize frequent clinical and psychiatric conditions from major depression through anxiety disorders to substance abuse [46].

1.2. The siege of metacognitive effectiveness

The pandemic and its control measures affected the mental health of the general population regardless of confirmed viral exposure at an unprecedented scale. Studies have often reported a severe increase in mental illnesses and behavioural disorders, especially in pathologies related to metacognitive performance, attributed to organic and functional deterioration [47,48,].

The expected consequences of the social, economic and health crisis created uncertainty – a constant threat for almost the entire population globally – and led to an increase in mental health disorders and behavioural changes regardless of age [49,50,51,52,53]. Among the adverse immediate effects of the existential crisis on mental health, post-traumatic stress disorder (PTSD) ranked first, followed closely by depression, anxiety and other behavioural and psychological disorders [54,55].

Insecurity and negative emotional attitudes are already known to affect cognitive performance [56,57,58], particularly in the areas of attention and executive functions [59,60], whereas psychological symptoms associated with existential threats disrupt circadian rhythms and disturb natural regeneration [61].

Traditional and social media have instantly generated – and maintained – panic [62,63], and the constant monitoring of news to tell fake and factual epidemiological information apart [64,65], the rise in media consumption [66], the lockdowns and other restrictions [67] have contributed to the exacerbation of psychosocial discomfort to different degrees [68,69]. Recent findings suggest that isolation and physical distancing itself [70] –

mistakenly echoed as social distancing, inducing fear of each other [71,72] – may also be responsible for functional uncertainty [73] and are associated with neuropsychological and neurobiological changes in early childhood and with age [74].

Crossing the blood–brain barrier enabled the virus to inflict direct damage – microlesions, acute inflammation – to the central nervous system [75,76,77,78,79,80,81] and even caused psychiatric and neuropsychiatric complications [82], whereas comparative analysis of exposed and virus-naïve samples revealed differences in executive functions but not in working memory performance [83]. Symptoms commonly associated with the infection and its long-term effects – e.g., cardiovascular and respiratory issues [84,85,86,87,88], fatigue [89], pain [90], brain fog [91], and sleep disorders [92,93] – were present in individuals with postvaccination syndrome (PVS) [94] and also affected brain functions and resulted in impaired cognitive capacity and learning abilities [95,96], while also altered behaviours and mood [97,98,99].

1.3. Beyond bias

“Metacognition and facial emotional expressions both play a major role in human social interactions [40,101] as inner narrative and primary communicational display, and both are limited by self-monitoring, control and their interaction with personal and social reference frames. Nonverbal communication holds significant importance in shaping interpersonal relationships, serving as a channel for expressing emotions and conveying information above content, it complements and alters primary meanings. Human emotion perception and recognition are automatic, enhanced by both organic (mirror neurons) and functional abilities (empathy).

Observation of facial muscles movements has been shown in many studies to be sufficient in itself to assess the emotional state of a subject [102-105] enabled by distinct neuronal pathways [106], and in specific cases to show universal patterns across species and cultures [107]. For the basic emotions – joy, surprise, anger, disgust, sadness, fear – it is generally accepted that they can be reliably described by identical faciomuscular movement configurations and that they have individual, social and other meanings beyond the expression of emotion. [108]

Although the recent academic debate argues whether or not emotions are directly linked to facial expressions and challenges the status quo that they are universally recognized as summarized by Heaven [109], Cowen et al. [110] suggests a high-dimensional framework to map the phenomena of human emotional expression and experience, highlighting the complexity of the field.

Recent studies conclude that while facial expressions are seemingly universal with a culturally dependent saturation of meaning, the underlying affective states rarely correlate with emotions that, in this sense, consist of spontaneous neurobiological changes and their cognitive evaluation, leading to cognition-dependent activation or inhibition of specific conscious responses and instinctive reflexes [111,112].

With the development of imaging and image analysis technologies, it has also become possible to code facial expressions and recognize emotions based on categorical [104] or continuous [113] models using artificial neural networks and machine learning in real time from recordings to use the resulting data for analysis, primarily for marketing purposes. [eg. 114,115] However, Automatic Facial Coding (AFC) systems developed to understand and influence consumers' emotions in line with profit driven purposes, are also ideally suited for psychological assessments, taking their limitations and potential into account and benefit both research and development [116].

The discrepancies of systematically manipulated content - e.g. the role of modalities, influence of artistic effects - in individual and social situations can be directly investigated when using high-quality videos recorded under laboratory conditions [117]. At the same time, when complemented with psychophysiological and psychometric measurement tools, AFC systems allow for sensitive data acquisition and – compared to traditional methods based on typically self-reported phenomenological interpretations – enables highly accurate statistical analysis, especially in the context of implicit process diagnostics [119].

A further advantage of video-based emotion recognition is that it can be analysed with a machine learning and artificial intelligence-enabled system, based on the judgement of emotion recognition experts – developed in time-consuming and expensive recruitment procedures – cross-referenced with relevant investigations, so that the human error can be eliminated in the analysis, resulting in AFCs to outperform humans [120].

Humans, compared to apes [121], exhibit reduced short-term visual memory in urban settings but excel in distinct cortical functioning eg. long-term memory, imagination, and intentionality in deceit detection."[17] Contrary to popular belief, the size difference alone would not matter in itself: the increased volume of the neocortex only supports reduced energy consumption by enabling improved resource allocation and distribution through advanced structural and functional effectiveness [118], enhancing cognitive capacity for logical thinking and intention attribution favoring long-term mating startegy assuring the survival of the species [122].

"Despite inherent inaccuracies [123], imagination plays a vital role in creating adaptive strategies for varying situations and stakes, hence assists risk assessment, meaning constant awareness and ability to mentally manipulate any and all information about the potential partner in order to reinforce or inhibit affiliation [124].

According to Ekman and Friesen [125], lying is nothing more than a dissonance of cognition and emotion that leads to nonverbal leakage along channels. The modality constraint and the separation of channels greatly affect the observer's picture of the observed person's affective-cognitive coherence - even without the content [126].

Analyzing facial expression, as a pivotal channel in human interactions [127], in terms of cognitive functions it is clear that it engages visual short-term and semantic visual memories associated with vision and its processing [128], just as much as the decoding of body language [129].

Human cognition extends beyond processing 'what is' to also consider 'what could be' in nonverbal communication as well, particularly deception detection, which relies on brief visual cues, with the 'presentation' time of micro-expressions being as short as 1/5-1/25 milliseconds [125,130]. The challenge lies in the detection of the emotional leakage that manifests in micro-expressions and contradicts the primary message. Detecting nonverbal leakage is complex, compounded by its atypical appearance. In human social interactions, distorted truths foster justifications, confirming suspicions and breeding stronger illusions to resolve cognitive dissonance.

While cognitive biases and stereotypes can be useful in everyday life, peer influence also puts evolutionary pressure on self-deception as an adaptive strategy [131], they are activated uncontrollably when the right risk (eg. time pressure, stakes, danger, emotional context) is present, and it is almost impossible to ignore them.

Just like in Flavell's [2] subjects, self-awareness is key to performance – from fast and accurate perception to being able to be simultaneously aware of a situation and its possible outcomes – and especially in communication, probabilistic prediction of intentions and successful manipulation of others – and a capacity that allows these simultaneous processes to perform efficiently – allows one to time the use of resources optimally, and being aware of both limitations and potentials. Awareness relieves cognitive capacity of unnecessary burdens, and volitional inhibition can be applied to types of nonverbal leakage that are more difficult to detect, while those that are easier to assess lead to more accurate – or, defined by the inner speech or narrative, self-assuring – findings [132].” [17]

2. OBJECTIVES

The aim of our study was to investigate associations of basic cognition, self-assessment and metacognitive abilities –metamemory and decisional awareness – without the usual statistical artefacts that stem from the bottom and top extremities, leaving less room for mathematical misinterpretation. Transforming the performance of the subject to a scale of 1 to 6 then titrating our sample task by task including groups from Group 2 to Group 5 only for analysis dcerease the risk of possible artefacts.

We have hypothesized that self-assessment bias is associated with metamemory and decisional awareness, and if so, strengthens metacognitive explanations regarding the ‘unskilled and unaware’ and the ‘dual burden’ arguments, that low performers are overconfident in their bad decisions.

The complex impact of the pandemic on human behaviour is reflected in the increased prevalence of clinical pathologies that are directly or indirectly associated with—or at least can be explained by—impaired metacognitive effectiveness; however, metamemory performance, decisional awareness and self-assessment have neither been studied in detail yet nor in the context of intergenerational and sex differences in association with COVID-19.

Our study also aimed to investigate a relatively large sample of mentally healthy working-age adults so that we could find novel associations of basic cognition, self-assessment and metacognitive abilities— metamemory and decisional awareness—when the first reports of the outbreak arrived. The collection of the third dataset was already scheduled when we started to suspect that either the virus, the control measures or both had affected metacognitive ability. Adverse experiences influence generations and sexes to different degrees [133], and as resilience [134], coping strategies [135], self-regulation [38], self-talk [132], and self-assessment are closely linked to metacognitive abilities, given the opportunity, we have decided to examine the periodical deviations in cognitive performance, metacognitive effectiveness and self-assessment in terms of generational and sex differences.

“In social interactions, intentional masking and display of emotional states lead to the appearance of micro-expressions and empathy-driven mimicry, therefore, we have hypothesised that the defining inner narrative enabled by self-awareness – based on self-confidence and personality – of a subject might project subconsciously and primes facial emotional expressions. To observe such phenomena and let faces serve as a purely inner-state dependent display, subjects were prevented from maintaining interaction during data collection, hence allowing honest – or at least less deceitful – reactions to stimuli.

While laboratory settings offer a sterile context to capture what might really be happening, they also miss out on revealing the real-life characteristics of social interactions.

As activation and inhibition of expressing emotions are motivated and enabled by individually different interplay of cognitive and affective factors, we have also hypothesized that the removal of direct social contact will promote the temporal and qualitative extension of facio-muscular activation and therefore reveal otherwise voluntarily or subconsciously hidden characteristics of the associations between self-confidence, personality traits and facial emotional expressions.

Our goal was to develop a setting that allows more space for the observation of the life-like approach to facial emotional expression using artistic and artificial experience as tools to understand the differences in emotional expressions and experiences between man-made and machine generated stimuli." [17]

H1 Self-assessment bias is associated with metamemory and decisional awareness

H2 COVID-19 affected sexes and generations to different extents regarding cognitive performance, metacognitive effectiveness and self-assessment in terms of generational and sex differences.

H3 Self-confidence (measured in self-assessment bias), personality traits and facial emotional expressions are interrelated.

3. METHODS

3.1. Sample characteristics

The study investigates a sample of self-reported mentally healthy, adult subjects (N=1394) based on availability and willingness who were tested online on their own devices. We then removed the top and bottom performers task by task after transforming their score to a scale ranging from 1 to 6 to match the scaling of the self-assessment, resulting in a final sample of 356 participants – 136 males (age=18-56; mean= 30.4; SD=9.16) and 220 females (age=18-55; mean= 29.9; SD=9.13) – who could therefore be at least 1 point optimistic or pessimistic in their self-assessment on a Likert scale of 6. [15]

The data of working-age subjects (N=1385, age=18-65) – Generation Z (GZ; born between 1997-2012), Millennials (GM; born between 1981-96), Generation X (GX; born between 1965-80), Boomers (GB; born between 1946-64) [136] – were collected in three major periods: before the outbreak (BL), after the first lockdown (W1) and at the end of the crisis (PC) and trimmed to investigate the effects of the pandemic of four generations. [16]

The main "study investigates a sample of 35 mentally healthy native Hungarian adult subjects – 14 men (age=28-51 years; M= 35.1 years) and 21 women (age=19-48; M = 30.8 years) who were attended to a screening of artistic and artificial stimuli, where their facial emotional expressions were recorded and analyzed by artificial intelligence." [17]

3.2. Apparatus

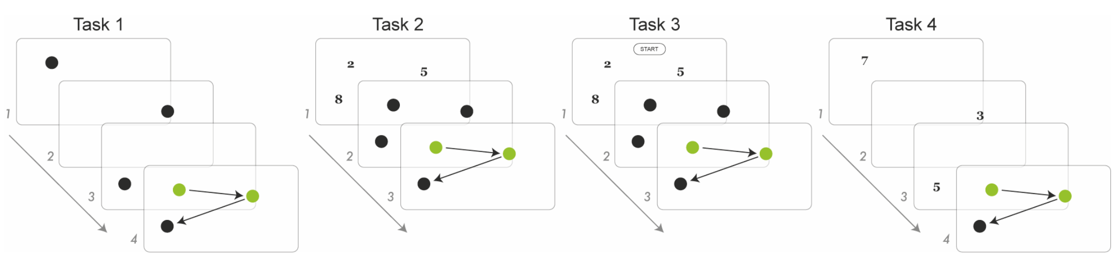

Figure 1. Test screens of the four computerized short term memory tasks. Task 1 and Task 4 require the recall of spatiotemporal sequence of dots (T1) or random single digit numerals (T4). Task 2 and 3 simultaneously presented

single digit numerals in numeric order in automated (T2) and self-paced (T3) limited-hold settings [17].

The four online short term memory tests – 2 learning levels (span from 3 to 4 stimuli) and 5 test levels (span from 5 to 9 stimuli) each – consisted of the computerised version of Corsi Block-Tapping Test (CBTT) [137] as a baseline task (Task 1) for its clinical and developmental relevance [138,139], the Inoue-Matsuzawa Masked Memory Task [140] in its original, limited hold (Task 2) and self-paced (Task 3) settings redesigned to measure metamemory faculty of metacognitive ability, while the last task was created based on CBTT to measure how subjects inhibit numero-spatiotemporal interference (Task 4) [141,142]. After each task, we have asked the participants to rate their performance compared to their peers on a Likert scale of 6. The computerisation of the tests enabled frontend action logging with millisecond accuracy, and provided the opportunity to our subjects to participate at a convenient time.

3.2.1. Laboratory equipment and setting

"Close-up studio cameras were set up in front of the subjects while they listened to the three literary excerpts in Hungarian with a total duration of 16 minutes interpreted by a professional actor in the following order: first with actor-performed audio (sound only), then with actor-performed experience (sound and image), and finally with artificially generated audio (sound only). After the first screening the order of stimuli was shuffled to avoid artefacts that may arise from order effect confound, despite the fact that we were only going to investigate modality dependent changes and individually specific emotion expressions." [17]

3.2.2. Facial action coding with artificial intelligence

"The FaceReader by Noldus uses an artificial neural network to classify emotional expressions, which yields data such as basic expressions, individual expressions, head orientation, gaze direction, personality characteristics, valence and arousal, as well as heart rate and heart rate variability with frame-by-frame resolution limited by the analyzed video material's frame rate and outputs data with milliseconds accuracy. By default, the diagnostic software measures the expression of the six basic emotions (joy, fear, anger, sadness, surprise, disgust) as a percentage and the temporal expression of the most prominent emotion along reaction time. A validation study conducted by Stöckli et al. [146] found that FaceReader 6 performed the best of the major emotion classification software available at the time, with an average accuracy of 88%. Another study done by Lewinski, den Uyl and Butler [119] states that FaceReader correctly recognized 88% of expressions on average in the WSEFEP and ADFES pictures, whereas human participants only recognized 85%, and outperforms humans 90 to 59% when it comes to neutral faces [120]. FaceReader 8.0 reached a higher test-retest reliability than human coders [147], and the since improved version of FaceReader - version 8.1 was used in this study - achieved an even higher score of 96% in emotional recognition according to the developer, so we can at least assume it is as good as or even better than human coders and valid in minimum 88% of the cases." [17]

3.3. Variables

The subjects reported their age and sex as biological variables.

We measured cognitive performance at the learning and test levels separately task by task and accumulated scores in all learning (P_{LA}) and all test phases (P_{TA}). We logged the reaction times of hits (RT) and false alarms (FA) with millisecond accuracy levels by level and task by task and averaged them into new variables (RT_{LA}=learning level average reaction time; RT_{TA}=test level average reaction time; FA_{LA}= learning level average false alarm reaction time; FA_{TA}= test level average false alarm reaction time). Memory performance P_{T1}-P_{T4} shows the number of hits across all the levels in the test phases of each task, P_{TA} is the average of them. RT_{T1}-RT_{T4} shows the average reaction time of hits across levels in each task, RT_{TA} is the average of all of them. FA_{T1}-FA_{T4} are the reaction times of false alarms, FA_{TA} is the average reaction time before mistaken recalls across all tasks. NP_{T1}-NP_{T4} are the 1-6 transformed versions of P_{T1}-P_{T4} that enabled us to filter out low (1-16%) and high (84-100%) performers by percentage ranges.

The main index of metacognition often referred as metamemory, MM, shows the total score improvement between the self-paced ($IMMMT_{SP}$) and limited hold ($IMMMT_{LH}$) settings of the Inoue-Matsuzawa masked memory tasks. DA_{T1}-DA_{T4} are another type of our metacognitive indices that show decisional awareness (DA), the ratio of average reaction times over average false alarm reaction times (DA=FA/RT) task by task, DA_{TA} is the average reaction time ratio across all tasks and shows if a subject was hesitant – the sign of knowing that they do not remember correctly – before false recall.

After each task, the participants were asked to rank their performance compared with that of their peers on a Likert scale of 6 (SA), which we translated into percentage values, then transformed the scores task by task into percentages and averaged their difference (SA-P_S) into the self-assessment bias index (SAB_{PA}). SA_1-SA_4 is the self-reported, raw self-assessment indices after each task. SAB_{P1}-SAB_{P4} shows the difference between actual and self-assessed performance in percentages task by task, while SAB_{PA} is its average across the tasks. ABS SAB_{PA} is the absolute deviation of the subjects' self-assessment bias from zero.

"Facial emotional expressions were recorded and analysed throughout the entire screening time with a chosen analysis frame rate of 30 frames per second resolution [148]– a unique ability of the artificial intelligence – into cumulated percentage values by basic (happy, surprised, sad, scared, disgusted, angry), other and neutral emotion category and each modality ('HV Angry 28.36' for the total percentage of anger expressed during each Human Video setting), then averaged into a modality-independent facial expression index ('A_E Angry 12.31').

Based on our preliminary exploration of the raw recordings and the collected data, we have identified the need to develop emotional expression ratios as new variables to be able to compare the characteristics across different modalities. Emotional Saturation (S_E) shows the ratio of 'dominant' to 'all other' emotions, to explore the subject's emotional span. Emotional Transparency (T_E) represents the ratio of 'basic six' to 'other' emotions and reveals how difficult might be to decode the social target's emotional state just by registering their facial expressions.

Since emotions and personality traits are interrelated [eg. 149,150], based on therapeutic considerations [151] we have grouped basic emotions into three personality categories – Extroversion (happy and surprised), Neuroticism (sad and scared) and Hostility (disgusted and angry) by Izard's theoretical framework and results [152] – to be able to analyse the associations of self-confidence and personality dimensions as defining factors of how subjects empathize, experience and express emotions." [17]

3.4. Statistical analyses

Spearman correlations Kruskal-Wallis tests and Brunner-Munzel tests – the most reliable nonparametric procedure for relatively small sample comparisons [143] – were performed with jamovi version 2.5 [144,145]. The threshold for statistical significance was set at $p < .05$.

3.5. Ethical declarations

All procedures complied with the Helsinki Declaration and institutional guidelines and were approved by Semmelweis University Regional and Institutional Committee of Science and Research Ethics at SE RKEB 149/2019 on 31st July 2019 and by the Institutional Research Ethics Committee at the Institute of Psychology at Károli University of the Reformed Church in Hungary (52/2019/P/ET & 36/2020/P/ET).

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4. RESULTS

4.1. Performance, metacognitive abilities and self-assessment

4.1.1. Differences between the original and the filtered sample

First, we wanted to understand whether there were any differences between our original and filtered samples. Removing the best and worst performers did not affect our original results much, subjects were correctly assessing their performance compared to their peers on average despite filtering extreme performers (Table 1; Figure 1).

Table 1. Based on self-assessment (SA_{T1}-SA_{T4}), Kruskal-Wallis tests show significant results with task performances (P_{T1}-P_{T4}) in both original and filtered samples. [15]

	Original sample (N=1394)				Filtered sample (N=356)			
	χ^2	df	p	ε^2	χ^2	df	p	ε^2
P_{T1} x SA_{T1}	173***	5	<.001	.1240	34.0***	5	<.001	.0959
P_{T2} x SA_{T2}	363***	5	<.001	.2600	31.6***	5	<.001	.0890
P_{T3} x SA_{T3}	485***	5	<.001	.3480	64.4***	5	<.001	.1820
P_{T4} x SA_{T4}	485***	5	<.001	.3480	41.8***	5	<.001	.1180

*Note. * p < .05, ** p < .01, *** p < .001*

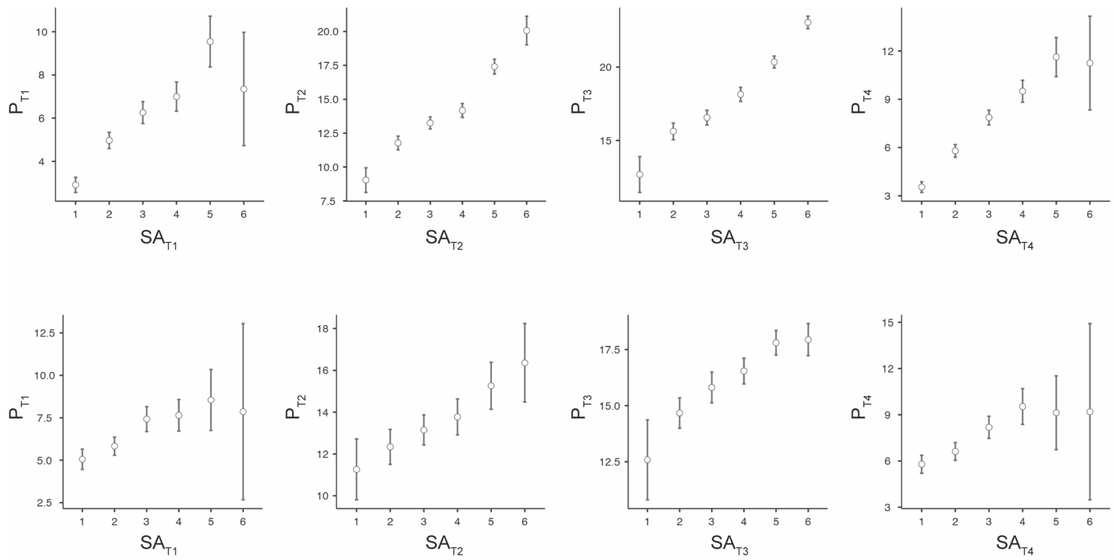

Figure 1. Based on self-assessment (SA_{T1}-SA_{T4}), Kruskal-Wallis tests yield significant results for task performance (P_{T1}-P_{T4}) means (º; 95% CI) in both original (top row) and filtered (bottom row) samples. [15]

4.1.2. Performance and self-assessment

From now on, we are reporting only the results of the filtered sample. The average self-assessment bias (SAB) was -.400 (SD=1.01), and was significantly associated with task performance with the exception of Task 3 (Table 2; Figure 2).

Table 2. Based on task performance (NP_{T1}-NP_{T4}), Kruskal-Wallis tests reveal that low performers are overconfident (SAB_{T1}-SAB_{T4}), and the better their actual performance the lower was their self-assessment rating (SA_{T1}-SA_{T4}). [15]

	Self-assessment (SA_{T1}-SA_{T4})				Self-assessment bias (SAB_{T1}-SAB_{T4})			
	χ^2	df	p	ε^2	χ^2	df	p	ε^2
NP_{T1}	**35.4*** **	3	<.001	.0996	**22.8*** **	3	<.001	.0643
NP_{T2}	**31.8*** **	3	<.001	.0896	**50.6*** **	3	<.001	.1430
NP_{T3}	**52.7*** **	3	<.001	.1490	5.21	3	0.157	.0147
NP_{T4}	**47.3*** **	3	<.001	.1330	**31.6*** **	3	<.001	.0891

Note. *N=356; * p < .05, ** p < .01, *** p < .001*

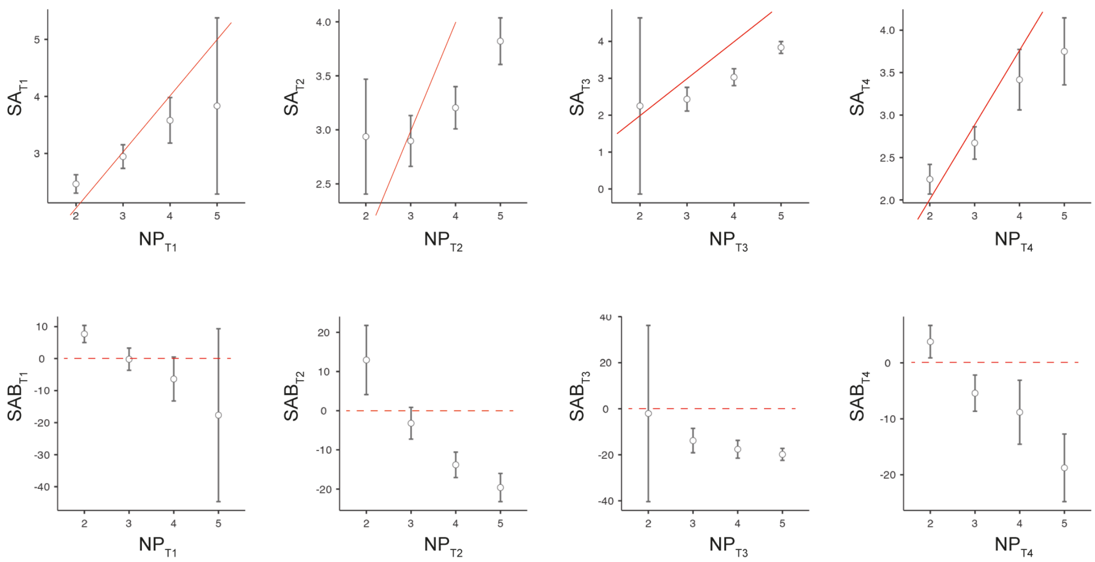

Figure 2. Based task performance (NP_{T1}-NP_{T4}) means (º; CI=95%) of the included four groups, the results of Kruskal-Wallis tests revealed that the better their actual performance (solid line) was, the lower their self-assessment rating (SA_{T1}-SA_{T4}), the more negative the bias (SAB_{T1}-SAB_{T4}) and only 'Group 3' was sometimes significantly close to zero bias (dashed line). [15]

4.1.3. Decisional awareness, performance and self-assessment

Low decisional awareness (DA) is associated with low performance and strengthens the "unskilled and unaware" argument on the 'dual burden' account, that low performers – often referred as incompetent – lack the metacognitive capacity to realize their mistakes on time. Investigating self-assessment (SA) and decisional awareness (DA) revealed that lower reaction times before false alarms are in line with lower self-assessment ratings (Table 3.)

Table 3. Kruskal-Wallis tests show low performers (P_{T1}-P_{T4}) are less aware of their bad decisions (DA_{T1}-DA_{T4}), and the lower the awareness the lower was their self-assessment score (SA_{T1}-SA_{T4}). [15]

	Performance (P_{T1}-P_{T4})				**Self-assessment (SA_{T1}-SA_{T4})**			
	χ^2	df	p	ε^2	χ^2	df	p	ε^2
DA_{T1}	122.0***	3	<.001	.3430	19.7**	5	.001	.0554
DA_{T2}	103.0***	3	<.001	.2890	12.0*	5	.035	.0338
DA_{T3}	14.8**	3	.002	.0418	9.28	5	.098	.0261
DA_{T4}	90.8***	3	<.001	.2560	12.5*	5	.028	.0353

*Note. N=356; * p < .05, ** p < .01, *** p < .001*

4.1.4. General associations

Spearman correlations revealed that the age of the subjects had a positive tendency with reaction time and a positive effect on false alarm reaction time.

Memory performance is positively associated with reaction time and decisional awareness, while negatively associated with false alarm reaction time, metamemory and self-assessment bias. Reaction time is positively associated with false alarm reaction time and decisional awareness but negatively affects metamemory.

False alarm reaction time is in negative association with decisional awareness, and positive tendency with self-assessment bias. Decisional awareness negatively associated with metamemory and self-assessment bias. Metamemory positively correlates with self-assessment bias. Self-assessment bias is also negatively associated with the absolute value of self-assessment bias (Table 4).

Table 4. Spearman correlations and Bayes Factors (BF_{10}) show how performance indices (performance=P; reaction time= RT; false alarm reaction time= FA), self-assessment (=SAB) and metacognitive abilities – metamemory (=MM) and decisional avareness (=DA) are associated with each other. [15]

		AGE	P_{TA}	RT_{TA}	FA_{TA}	DA_{TA}	MM	SAB_{PA}
P_{TA}	Spearman's rho	-.049	—					
	p-value	.352	—					
	BF_{10}	.2892						
RT_{TA}	Spearman's rho	**.126***	**.488*****	—				
	p-value	.017	<.001	—				
	BF_{10}	4.6222	1.44e +7					
FA_{TA}	Spearman's rho	**.170****	**-.416*****	**.225*****	—			
	p-value	.001	<.001	<.001	—			
	BF_{10}	893.4652	67598.4169	742.581				
DA_{TA}	Spearman's rho	-.070	**.520*****	**.362*****	**-.546*****	—		
	p-value	.185	<.001	<.001	<.001	—		
	BF_{10}	1.0544	1.48e +22	2102.005	1.11e +15			
MM	Spearman's rho	-.073	**-.171****	**-.292*****	.060	**-.187*****	—	
	p-value	.171	.001	<.001	.263	<.001	—	
	BF_{10}	.1690	4.1144	48330.620	.0700	34.5539		
SAB_{PA}	Spearman's rho	.069	**-.168****	-.104	**.117***	**-.140*****	**.154****	—
	p-value	.196	.001	.051	.027	.008	.004	—
	BF_{10}	.3601	125.1165	.169	.1011	6.7650	5.044	
ABS SAB_{PA}	Spearman's rho	.029	.031	.062	.018	.017	-.089	**-.520*****
	p-value	.591	.563	.242	.734	.752	.093	<.001
	BF_{10}	.0749	.0824	.117	.0746	.0907	.1830	6.3e +8

Note. *N=356; df=354; * p < .05, ** p < .01, *** p < .001*

4.2. Performance and metacognitive abilities during the pandemic

4.2.1. Baseline associations

Older subjects before COVID-19 scored lower in both the learning (P_{LA}) and test phases (P_{TA}), were overconfident (SAB_{PA}) and tended to be more hesitant before mistakes (FA_{TA} and DA_{TA}). The better learners (P_{LA}) were better performers (P_{TA}), scored slower (RT_{TA}) but failed quicker (FA_{TA}), improved less in the metamemory task (MM), depreciated their performance (SAB_{PA}) and were less aware of their wrong decisions (DA_{TA}).

Those with better metacognitive skills (MM; SAB_{PA}; DA_{TA}) were also slower in scoring (RTTA) and failing (FATA). Decisional awareness (DA_{TA}) is positively correlated with metamemory performance (MM) and overconfidence (SAB_{PA}) (Table 5).

Table 5. Spearman correlations of the baseline sample (N=392) before COVID-19 revealed associations with age, learning and test performance (P_{LA}; PLT), reaction time (RT_{TA}; FA_{TA}) and metacognitive ability (MM; SAB_{PA}; DA_{TA}). [16]

BASELINE		AGE	P_{LA}	P_{TA}	RT_{TA}	FA_{TA}	MM	SAB_{PA}
P_{LA}	Spearman's rho	-.169 ***	—					
	p value	<.001	—					
P_{TA}	Spearman's rho	-.202 ***	.431 ***	—				
	p value	<.001	<.001	—				
RT_{TA}	Spearman's rho	-.065	.185 ***	.575 ***	—			
	p value	.201	<.001	<.001	—			
FA_{TA}	Spearman's rho	.113 *	-.154 **	-.482 ***	-.036	—		
	p value	.025	.002	<.001	.473	—		
MM	Spearman's rho	-.013	-.162 **	-.133 **	-.273 ***	.198 ***	—	
	p value	.792	.001	.008	<.001	<.001	—	
SAB_{PA}	Spearman's rho	.153 **	-.195 ***	-.281 ***	-.142 **	.140 **	.028	—
	p value	.002	<.001	<.001	.005	.005	.578	—
DA_{TA}	Spearman's rho	.109 *	-.194 ***	-.714 ***	-.545 ***	.704 ***	.198 ***	.156 **
	p value	.031	<.001	<.001	<.001	<.001	<.001	.002

*Note. N= 392; * p < .05, ** p < .01, *** p < .001*

4.2.2. Before, during and after COVID-19

In general, COVID-19 negatively affected short-term memory during the learning phase (P_{LA}) more strongly during the first lockdown (W1), whereas scores in the self-paced setting ($IMMMT_{SPT}$) of the tests and metamemory performance (MM) constantly decreased over time in the analysed sample.

Male subjects learned (RT_{LA}) and failed (FA_{TA}) more slowly but scored quicker (RT_{TA}) and more quickly in $CBTT_{T}$ and less so in $IMMMT_{SPT}$ and MM than did women, who were initially (BL) more confident, suddenly (W1) became more uncertain and then quicker again (PC) in their bad decisions (DA_{TA}).

Table 6. Kruskall–Wallis tests revealed differences between subjects in pandemic periods (C-19), periodical sex (C-19×SEX) and generational (C-

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19×GEN) differences and the interaction of sex and generations over time (C-19×SEX×GEN).). [16]

	C-19					C-19×SEX					C-19×GEN					C-19×SEX×GEN				
	χ^2	df	p		ε^2	χ^2	df	p		ε^2	χ^2	df	p		ε^2	χ^2	df	p		ε^2
$CBTT_L$	5.7518	2	.056		.00416	9.32	5	.097		.00673	**74.33**	**11**	**<.001**	***	**.05370**	**88.2**	**22**	**<.001**	***	**.06370**
$IMMMT_{LHL}$	4.7164	2	.095		.00341	8.77	5	.119		.00634	**45.68**	**11**	**<.001**	***	**.03301**	**56.2**	**22**	**<.001**	***	**.04060**
$IMMMT_{SPL}$	.0463	2	.977		3.34E-05	4.54	5	.475		.00328	3.46	11	.983		.00250	27.6	22	.190		.01990
P_{LA}	**6.1253**	**2**	**.047**	*	.00443	6.47	5	.263		.00468	**72.15**	**11**	**<.001**	***	**.05213**	**8.2**	**22**	**<.001**	***	**.05790**
RT_{LA}	1.4314	2	.489		.00104	**24.95**	**5**	**<.001**	***	**.01805**	**43.97**	**11**	**<.001**	***	**.03182**	**83.0**	**22**	**<.001**	***	**.06000**
FA_{LA}	1.4337	2	.488		.00245	2.48	5	.779		.00423	17.32	11	.099		.02955	28.0	22	.176		.04780
$CBTT_T$	3.0446	2	.218		.0022	**26.25**	**5**	**<.001**	***	**.01896**	**78.52**	**11**	**<.001**	***	**.05673**	**11.3**	**22**	**<.001**	***	**.07970**
$IMMMT_{LHT}$	2.1131	2	.348		.00153	6.21	5	.286		.00449	**52.37**	**11**	**<.001**	***	**.03784**	**66.1**	**22**	**<.001**	***	**.04780**
$IMMMT_{SPT}$	**13.5205**	**2**	**.001**	**	**.00977**	**14.33**	**5**	**.014**	*	**.01035**	**53.15**	**11**	**<.001**	***	**.03840**	**64.8**	**22**	**<.001**	***	**.04680**
P_{TA}	4.8571	2	.088		.00351	9.34	5	.096		.00675	**79.98**	**11**	**<.001**	***	**.05779**	**95.9**	**22**	**<.001**	***	**.06930**
RT_{TA}	.0965	2	.953		7.01E-05	**15.21**	**5**	**.009**	**	**.01106**	17.36	11	.098		.01262	**64.8**	**22**	**<.001**	***	**.04710**
FA_{TA}	3.5638	2	.168		.00258	**17.86**	**5**	**.003**	**	**.01291**	**91.5**	**11**	**<.001**	***	**.06616**	**107.8**	**22**	**<.001**	***	**.07790**
MM	**9.465**	**2**	**.009**	**	**.00684**	**11.92**	**5**	**.036**	*	**.00861**	**24.02**	**11**	**.013**	*	**.01736**	3.1	22	.116		.02180
SAB_{PA}	5.4122	2	.067		**.00391**	**43.67**	**5**	**<.001**	***	**.03156**	**31.65**	**11**	**<.001**	***	**.02287**	**78.6**	**22**	**<.001**	***	**.05680**
DA_A	2.6501	2	.266		**.00193**	**12.69**	**5**	**.026**	*	**.00923**	**54.24**	**11**	**<.001**	***	**.03945**	**72.6**	**22**	**<.001**	***	**.05280**

*Note. N=1385; * p < .05, ** p < .01, *** p < .001*

The gender gap further deepened during the pandemic with respect to self-assessment (SAB_{PA}), as both sexes were negatively biased at the beginning of the sampling period, but while men improved their original accuracy, women remained almost as self-depreciating as they were (Table 6-7, Figure 3)

We were able to reveal generational differences regarding almost every observed aspect except for the self-paced setting ($IMMMT_{LA}$), the false alarm reaction time (FA_{LA}) in the learning phase, and the reaction time during the test phase (RT_{TA}). Millennials (GM), despite being the slowest (RT_{LA}; RT_{TA}), outperformed everyone else in the test phase (P_{TA}) before the outbreak (BL) and at the end of the crisis (PC).

Table 7. Heatmap of percentage fluctuations (Δ; red=increase, blue=decrease) of means relative to the pre-pandemic baseline (BL) average over time (W1=end of first lockdown, PC=end of restrictions) across generations (GZ=Generation Z; GM=Millennials; GX= Generation X; GB= Baby Boomers) and sex (male and female) in test performance (P_{TA}), metamemory (MM), decisional awareness (DA_{TA}) and self-assessment bias (SAB_{PA}).). [16]

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		MEAN	Δ (%)	GZ	Δ (%)	GM	Δ (%)	GX	Δ (%)	GB	Δ (%)
PTA	BL	13.10	0.0	13.20	0.8	13.80	5.3	11.80	-9.9	9.17	-30.0
	MALE	13.00	-0.8	12.60	-3.8	13.80	5.3	11.70	-10.7	11.80	-9.9
	FEMALE	13.20	0.8	13.40	2.3	13.80	5.3	11.80	-9.9	7.29	-44.4
	W1	12.50	-4.6	12.10	-7.6	13.00	-0.8	11.60	-11.5	7.89	-39.8
	MALE	12.90	-1.5	12.50	-4.6	13.00	-0.8	12.80	-2.3	NaN	NaN
	FEMALE	12.30	-6.1	11.80	-9.9	12.90	-1.5	11.00	-16.0	7.89	-39.8
	PC	12.60	-3.8	13.20	0.8	12.40	-5.3	10.70	-18.3	8.93	-31.8
	MALE	12.80	-2.3	13.40	2.3	12.30	-6.1	11.50	-12.2	5.00	-61.8
	FEMALE	12.40	-5.3	13.00	-0.8	12.40	-5.3	10.40	-20.6	9.92	-24.3
MM	BL	5.14	0.0	4.95	-3.7	5.19	1.0	5.19	1.0	6.33	23.2
	MALE	5.56	8.2	5.19	1.0	5.76	12.1	5.60	8.9	5.60	8.9
	FEMALE	4.93	-4.1	4.86	-5.4	4.85	-5.6	4.95	-3.7	6.86	33.5
	W1	4.92	-4.3	4.49	-12.6	4.47	-13.0	5.93	15.4	9.83	91.2
	MALE	5.05	-1.8	3.67	-28.6	4.72	-8.2	6.51	26.7	NaN	NaN
	FEMALE	4.85	-5.6	5.19	1.0	4.35	-15.4	5.62	9.3	9.83	91.2
	PC	3.94	-23.3	4.03	-21.6	3.06	-40.5	4.96	-3.5	4.60	-10.5
	MALE	3.55	-30.9	3.82	-25.7	2.69	-47.7	3.96	-23.0	10.00	94.6
	FEMALE	4.23	-17.7	4.20	-18.3	3.42	-33.5	5.44	5.8	3.25	-36.8
DATA	BL	2.37	0.0	2.44	3.0	2.08	-12.2	2.90	22.4	2.86	20.7
	MALE	2.38	0.4	2.69	13.5	2.06	-13.1	2.95	24.5	1.54	-35.0
	FEMALE	2.37	0.0	2.35	-0.8	2.09	-11.8	2.87	21.1	3.80	60.3
	W1	2.77	16.9	2.51	5.9	2.37	0.0	3.24	36.7	14.50	511.8
	MALE	2.17	-8.4	2.41	1.7	1.99	-16.0	2.49	5.1	NaN	NaN
	FEMALE	3.09	30.4	2.60	9.7	2.56	8.0	3.65	54.0	14.50	511.8
	PC	2.57	8.4	2.31	-2.5	2.55	7.6	3.34	40.9	6.81	187.3
	MALE	2.60	9.7	2.44	3.0	2.58	8.9	3.12	31.6	13.00	448.5
	FEMALE	2.55	7.6	2.20	-7.2	2.53	6.8	3.45	45.6	5.26	121.9
SABPA	BL	-9.11	0.0	-11.40	-25.1	-9.08	0.3	-6.76	25.8	3.60	139.5
	MALE	-6.56	28.0	-4.28	53.0	-9.18	-0.8	-4.43	51.4	0.32	103.5
	FEMALE	-10.40	-14.2	-14.10	-54.8	-9.03	0.9	-8.08	11.3	5.95	165.3
	W1	-7.56	17.0	-1.05	88.5	-9.89	-8.6	-4.86	46.7	8.47	193.0
	MALE	-4.55	50.1	2.93	132.2	-8.18	10.2	0.86	109.4	NaN	NaN
	FEMALE	-9.16	-0.5	-4.46	51.0	-10.80	-18.6	-7.91	13.2	8.47	193.0
	PC	-5.88	35.5	-6.84	24.9	-4.83	47.0	-3.39	62.8	-14.20	-55.9
	MALE	-1.58	82.7	-2.23	75.5	-0.75	91.7	0.27	102.9	-10.70	-17.5
	FEMALE	-9.22	-1.2	-10.60	-16.4	-8.63	5.3	-5.12	43.8	-15.10	-65.8

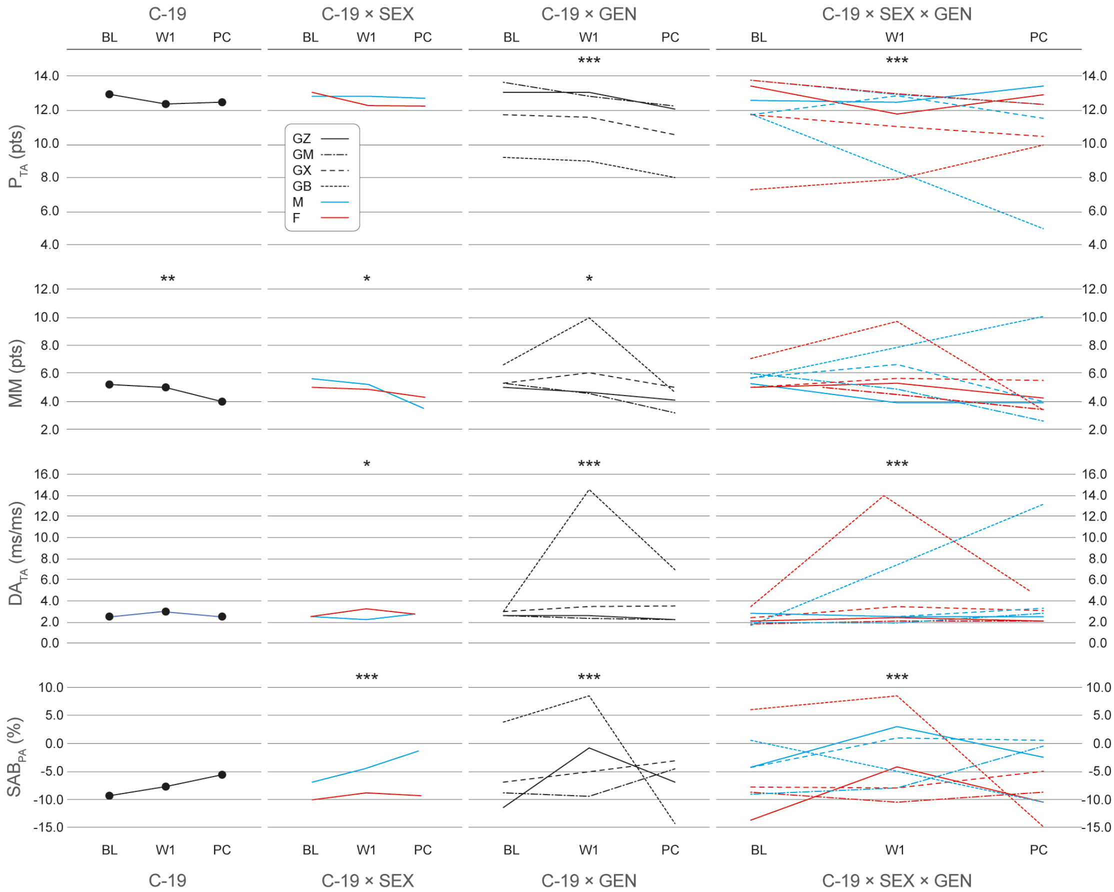

Figure 3. Kruskall–Wallis tests revealed differences between subjects by pandemic period in general (C-19), periodical sex (C-19×SEX; Male: blue line; Female: red line) and generational (C-19×GEN) differences and the interaction effects of sex and generations over time (C-19×SEX×GEN) on test performance (P_{TA}), metamemory (MM), decisional awareness (DA_{TA}) and self-assessment bias (SAB_{PA}).). [16]

Generation Z (GZ) could take the lead for a short while during the first wave (W1), whereas Boomers (BM) were the quickest (RT) and least successful (P). Metamemory performance (MM) decreased over time, with a spike in each generation at W1, similar to decisional awareness (DA_{TA}); however, the latter increased by the end of restrictions (PCs) for GX and GB.

The original order of self-assessment bias (SAB_{PA}) changed the most during the observed period for GB, whose overconfidence at the beginning further increased by W1 but became the least optimistic at the end. The baseline bottom Generation Z improved self-confidence (SAB_{PA}) almost to accuracy, whereas Millennials became the most pessimistic at W1, but all returned to the original ranks of bias with a slight overall increase in optimism. In contrast to other generations, GX improved in their self-assessment constantly and became the most accurate group at the end of the sampling period.

The within- and between-generational sex differences varied the most at the end of the first lockdown (W1), rearranging the rankings of performance (P_{TA}), decisional awareness (DA_{TA}) and self-assessment bias (SAB_{PA}) indices by the end of the pandemic, as expected, on the basis of our previous findings [154]; however, there were no significant disparities in metamemory (MM) performance between the groups.

4.3. Performance, metacognitive abilities and emotion

"Brunner-Munzel testing confirmed no evidence of sex differences (Table 8) in our sample regarding age (Age), memory performance (P), self-assessment bias (SAB), self-assessment accuracy (A_{SAB}) and polarity (P_{SAB})." [17]

Table 8. Brunner-Munzel tests confirms no evidence of differences between basic variables (Age, Memory Performance, Self-Assessment Bias, Accuracy and Polarity) and sex. [17]

	Statistic	df	p	Relative effect
AGE	-1.559	31.8	.129	.350
P	-0.182	29.9	.857	.481
SAB	-0.441	28.9	.662	.459
A_{SAB}	0.406	24.3	.688	.524
P_{SAB}	-0.538	27.9	.595	.452

Note. H_a $\hat{P}(1 < 2) + ½\hat{P}(1 = 2) \neq ½$

"Compared to audio presentation (sound only), the full artistic experience (sound and video) seemingly rather dimmed than enhanced emotional expressions. Contrary to our expectations, Kruskal-Wallis testing of emotional expressions by modalities – Human Audio, Human Video, Artificial Audio and their modality-independent Average – confirmed no evidence of such phenomena (Table 9)." [17]

Table 9. Kruskal-Wallis tests confirm no evidence of differences between each modality (HA, HV, AA) and their average (AE). [17]

Emotion	χ^2	df	p	ε^2
Neutral	0.740	3	.864	.00532
Happy	0.741	3	.863	.00533
Surprised	2.249	3	.522	.01618
Sad	0.608	3	.895	.00437
Scared	2.015	3	.569	.01449
Disgusted	0.540	3	.910	.00388
Angry	3.074	3	.380	.02212
Other	5.107	3	.164	.03674
S_E	1.801	3	.615	.01296
T_E	0.343	3	.952	.00247
Extroversion	1.473	3	.689	.01060
Neuroticism	0.530	3	.912	.00382
Hostility	2.511	3	.473	.01807

"General analysis of the sample revealed that self-assessment bias is moderately associated with the expression of anger (χ^2= 7.3736, df=2, p=0.25, ε^2=0.21687) and hostile tendency (χ^2= 7.4567, df=2, p=0.24, ε^2=0.21931). Surprisingly and quite contrary to our expectations based on a previous phenomenological approach [153] the difference between the expressions of other basic emotions were not significant (Table 10)." [17]

Table 10. Kruskal-Wallis tests confirm evidence of differences between self-assessment bias (SAB) and the average of facial emotional expressions (AE Angry, AE Hostility). [17]

Emotion	χ^2	df	p	ε^2
Neutral	3.7451	2	.154	.11015
Happy	2.3276	2	.312	.06846
Surprised	0.0597	2	.971	.00176
Sad	2.0917	2	.351	.06152
Scared	1.5000	2	.472	.04412
Disgusted	2.6545	2	.265	.07807
Angry	7.3736	2	.025*	.21687
Other	5.3169	2	.070	.15638
S_E	3.5787	2	.167	.10526
T_E	2.7109	2	.258	.07973
Extroversion	1.3546	2	.508	.03984
Neuroticism	2.0917	2	.351	.06152
Hostility	7.4567	2	.024*	.21931

"Categorical grouping and Brunner-Munzel testing (Table 11) of our sample by accurate or biased self-assessment (A_{SAB}) confirmed evidences that Neutrality (BM=2.97, df=5.58, p=0.014, RE=0.798) as lack the of detectable expressions and Transparency (BM=2.33, df=26.01, p=0.014, RE=0.702) as the incidence of basic emotional expressions was strongly higher, while Saturation (BM=-2.62, df=9.08, p=0.005, RE=0.210) as the variety of emotional experiences was moderately lower in the biased group." [17]

Table 11. Brunner-Munzel tests confirm evidence of differences by self-assessment bias accuracy (ASAB) and emotional neutrality, emotional saturation (S_E) and emotional transparency (T_E) across modalities and their average (A_E). [17]

Emotion	Modality	Statistic	df	p	Relative effect
Neutral	HA	1.88	8.96	.047*	.694
	HV	2.87	4.20	.021*	.815
	AA	4.03	5.50	.004**	.847
	A_E	2.97	5.58	.014*	.798
S_E	HA	-2.72	14.51	.008**	.258
	HV	-1.87	4.27	.065	.258
	AA	-2.62	7.56	.016*	.242
	A_E	-3.26	9.08	.005**	.210
T_E	HA	1.33	3.96	.128	.694
	HV	1.14	4.18	.158	.665
	AA	4.11	12.28	< .001***	.819
	A_E	2.33	26.01	.014*	.702

Note. n=35; $H_a\ \hat{P}(1 < 2) + ½\hat{P}(1 = 2) > ½$

"Exploring the differences between modalities, the artificial audio (AA) setting emerged both in emotional Neutrality (BM=4.03, df=5.50, p=0.004, RE=0.847) and Transparency (BM=4.11, df=12.28, p<0.001, RE=0.819) in the biased group with a strong relative effect, while the human audio (HA) setting elicited moderately Saturated expressions (BM=-2.72, df=14.51, p=0.008, RE=0.258) in the accurate group. Brunner-Munzel tests revealed (Table 12) relatively strong associations of positive bias polarity (P_{SAB}) and Hostility across modalities and their Average (BM=2.91, df=33.0, p=0.003, RE=0.732), as a result of strong synergetic tendencies of Disgust (BM=1.74, df=27.0, p=0.047, RE=0.608) and Anger (BM=2.35, df=27.0, p=0.013, RE=0.670). Altogether, the subjects of the observed sample reacted typically with neutral expressions to the presented stimuli, which can be explained by the reduced attentional capacity and the resulting lower receptivity and empathy due to the fear of the epidemic and the stress arising from the restrictions, as well as by the laboratory situation itself." [17]

Table 12. Brunner-Munzel tests confirm evidence of differences by self-assessment bias polarity (P_{SAB}) and Disgust, Anger and Hostility across modalities and their average (A_E). [17]

Emotion	Modality	Statistic	df	p	Relative effect
Disgusted	**HA**	**1.74**	**27.0**	**.047***	**.608**
	HV	1.67	29.0	.053	.605
	AA	0.97	30.1	.171	.552
	A_E	1.67	29.0	.053	.605
Angry	**HA**	**2.35**	**27.0**	**.013***	**.670**
	HV	1.67	29.0	.053	.605
	AA	1.46	25.0	.078	.585
	A_E	**2.40**	**31.9**	**.011***	**.681**
Hostility	**HA**	**3.38**	**31.3**	**< .001*****	**.755**
	HV	**1.93**	**32.9**	**.031***	**.647**
	AA	**1.82**	**30.7**	**.039***	**.632**
	A_E	**2.91**	**33.0**	**.003****	**.732**

Note. n=35, H_a $\hat{P}(1 < 2) + ½\hat{P}(1 = 2) > ½$

"It is also a surprising result that despite the lack of direct evidence of emotional experience difference between modalities, we have found strong but modality-dependent associations with self-assessment bias and emotional expressions, which leads to several conclusions:

a) that the actor's predominantly negative-neutral facial expressions influence the recipient's facial expressions in terms of affective transfer; and

b) that the emotional intensity of the audio-only experience is higher because this form presumably allows more room for imagination, hence reserves cognitive processing power to the detriment of the control of facial expressions.

The artificial sound, on the other hand, has often resulted both in temporary serenity in case of negative emotions and in enhanced positive emotions, most probably because of its comic intonation and inconsistent emphasis which were violating natural patterns, resulting in relatively strong associations between self-assessment accuracy, emotional transparency and neutrality. Accurate self-assessment is associated with lower facial emotional control (lower Neutrality), higher emotional Saturation and lower Transparency, compared to any sign of bias, while Anger and Hostility are typical in the overconfident group." [17]

5. DISCUSSION

As we hypothesized, self-assessment bias is associated with metamemory and decisional awareness. Score transformation of memory performance to match the Likert scale of self-assessment allowed us to remove Group 1 and Group 6 – the worst and best performers – from the original sample so we could create an opportunity that allowed subjects to be almost equally optimistic or pessimistic on the margins as in the middle, hence removing the effect of possible artefacts that the mathematical models revealed.

The age of the subjects did not affect average cognitive performance, either because of the short age span or because of the removal of best and worst performers, however, it was associated with slower reaction times both for hits and for false alarms. High performers acquired hits more quickly and were more aware of their mistakes as expected, confirming the capacity dependent nature of metacognitive abilities. The significant associations between high self-assessment bias and low performance and low decisional awareness and a correlation with metamemory clearly show that self-assessment is partly a metacognitive task, that – without any feedback during the tests –intuitively processed and is essential where accurate performance-based judgments are necessary, mainly in collaboration and social effectiveness.

Instead of the usual statistical manipulations, we were able to design the experiment with the purpose of trimming the edges based on performance and explore how self-assessment bias persists and fundamentally similar to previous findings. Despite remote – or online – testing has its own strengths and limitations [155,156], computerisation provided us with the ability to record the actions of our subjects with millisecond accuracy, not to mention the ease of access to a relatively large sample in a short period of time. Although we have not controlled our study for computer literacy, we strongly believe that in light of that we have calculated our only reaction-time based variable – decisional awareness – depending on the subjects' own pace, that effect negligible.

Due to a performance confound, metamemory index can be higher for those who scored relatively less during automatic pacing of the limited hold memory test [157], however, with the elimination of bottom and top performers we might have corrected our results for this effect, as we have not found any age-related differences [158]. Intrinsic motivation [159], having it or not, may also affect the results of metacognitive judgements as the subjects knew whether or not they were exerting sufficient effort into completing the tasks, and having more control [160] may have improved the performance of the subjects between Task 3 and Task 2. Metacognitive abilities are mostly studied in younger subjects; therefore, we hope that our sample characteristics allow us to generalize our results to mentally healthy working-age populations with the usual limitations of near-university samples [161] and cultural characteristics [162], assuming that the tasks – especially CBTT – required sufficient effort to enable us the exclusion of subjects with – even the mildest – cognitive impairment.

In general, COVID-19 affected sexes and genarations to different extents regarding cognitive performance, metacognitive effectiveness and self-assessment in terms of generational and sex differences. We revealed continuous decay in metamemory performance regardless of age and sex—an alarming discovery from the therapeutic aspect [163,164]—during the investigated periods (BL, W1 and PC), the probable result of—unlike the expected performance-related explanations [165] based on the scores of our subjects—changes in mood and attitude that manifested in demotivation [39,166], isolation and social deprivation led to the underutilization of metacognitive abilities [167], or a direct effect of SARS-CoV-2 exposure in addition to previous results [83,168,169].

The exploration of self-assessment revealed that subjects initially underrated their performance in general; however, men displayed more confidence by default and further improved their accuracy over time until they were almost realistic. The lower self-assessment scores of female subjects might reflect their low self-confidence [170] because they judge themselves too harshly [171].

The most surprising of all generational differences was that although Boomers endured the most throughout their lifespan and we were expected to be the least vulnerable to adverse experiences [172], Boomers have suffered the most damage—likely because isolation had a greater impact on them [173] or their offspring were at such risk for the first time—during the investigated period, whereas other generations deviated from default during the first lockdown and almost returned to their original scores by the end of the crisis. Another observation comparing Gen B to other generations concerns decisional awareness, the metacognitive index measuring the ratio between the reaction times of false alarms and hits, where they displayed significant hesitation before mistakes, almost as if they had lost track of what they were doing [174]. Boomers also deviated the most from default in self-assessment, ranked themselves the highest by the end of the first lockdown, and became the least confident at the end of the crisis among the observed generations, possibly because self-assessment requires metacognitive and intuitive processes, since there was no performance-related feedback during the tasks. Given the time-sensitive nature of short-term memory tests [175], including the implicit registry of results during the tasks and considering the mental health correlates of metacognitive effectiveness, measuring such uncertainties might contribute to the development of novel preventive diagnostic methods of all related psychopathologies in the future, especially if subjects are profoundly assessed and even the slightest subclinical deviances are explored beforehand and not just reporting a *sine morbo* mental status.

Additionally, we cannot completely rule out the effect of the – morally obliged, peer pressured, heavily incentivized or often even employer-mandated, but definitely discriminating and socially polarizing [176] – vaccination on metacognition in light of recent studies that examined how vaccine-related local and systemic side effects [177,178], especially in the case of mRNA-based immunization [179,180], including organic [181] and functional neurological disorders [182,183,184], and further increased the severity of the mental burden for affected individuals [185].

The main “aim of the study was to investigate how cognitive capacity and metacognitive abilities relate to facial emotional expressions, we found that self-confidence (measured in self-assessment bias), personality traits and facial emotional expressions are interrelated. The short-term memory tasks were essential to measure an objective output in a non-familiar situation, on which subjects were able to intuitively reflect on and estimate their performance on a scale of 1-6 compared to peers. Processing these objective and subjective factors gained us access to the individually attributive degree of self-assessment bias, which allowed the exploration of the subjects’ inner narrative without the typical influencing factors of self-reported results. To let faces serve as a purely inner-state dependent display, subjects were prevented to maintain interaction during the screening, hence allowing unfiltered – or at least less voluntary – facial emotional reactions to stimuli.

As we have hypothesised, the defining inner narrative of a subject projects subconsciously towards peers and influences facial emotional expressions. The intensity of facial emotional expression depends on whether and to what extent the subject is organically and functionally able and willing to communicate emotional state to others in a given situation. Cognitive capacity directly determines the ability of self-control – associated with the approach or inhibition of certain behaviours – and metacognitive ability which together influence self-awareness, social interactions, and are particularly relevant in the case of intentional expression or repression of facial emotions. However, in the applied laboratory setting none of this mattered: subjects were practically prevented interaction, and their purely receiving role allowed us to observe facio-muscular reactions without their normally active facial expression filters.

Happiness, sadness and surprise appeared on the faces regardless of the array and magnitude of self-assessment bias, leading us to a conclusion that their inner narrative aligned with past experiences and primes expressions by eliciting sympathy and support in others for the results – whether they lag behind promises or meet expectations – might be independent of self-confidence. Hostile – disgust and mainly anger – emotional expressions, on the contrary, stem in overconfidence and mitigates the expected harm that might be done by others for the results are thought to fall short of requirements, providing a higher ground in a predicted conflict on a ‘best defense is attack’ basis and as a constructive, reparative response [186]. Our finding indicates that further research may explore how overconfidence exactly relates to inner speech, the expression of anger and hostility, and whether and how these results might serve therapeutic aspects.

Neutrality and happiness were detected in cases of congruent self-reflection, independent of cognitive capacity but related to gender disparities. Male subjects of minimally biased or precise self-assessment seemingly enjoyed the screening more than females, which can either be attributed to

a) the male actor’s appearance or the play itself,

b) the mood and topics of the literary excerpts, or

c) simply the fact they were able to relax and focus on the experience of having a normally peaceful inner narrative due to their accurate self-reflection and social reference frame.

In conclusion, self-assessment bias seemingly related to how subjects manipulate their environment, and depending on their projected expectations based on past experiences, self-confidence and personality, their expression reflected on how they want others to see them: hostile, friendly or lost.

The costs and benefits of expressing or repressing emotional states are purely situational and depend on capacity and motivation. Whilst in social interactions sympathy, empathy – a special form of metacognition, being aware and in control of feelings – and intention define verbal-nonverbal congruency, inhibition of emotional leakage becomes futile for subjects who are experiencing temporary social deprivation or isolation.

The reception of artistic performance as a one-way communication triggered more intense emotional reactions when imagination reserved cognitive capacity, while the appearance of the actor saturated the experience resulting in similar, but decreased amplitude of facial expressions. Observing such phenomena allows us to conclude that artistic audio-visual experience might develop empathy and empathetic skills by solitary exploration of affective changes which improve self-awareness by practicing adaptation to another person without the consequences of the attempt.

In conclusion, the removal of direct social contact promotes the temporal and qualitative extension of facial emotional expressions and therefore linked to cognitive capacity, metacognitive abilities and personality traits.

Although the relatively small sample size, the self-reported mental health status and known effects of the pandemic – and its due restrictions – on cognitive abilities [187,188] prevent us from directly generalize these findings to the majority of the population, our results indicate that further investigation of the yet revealed pattern would be beneficiary in the development of diagnostic tools and therapeutic interventions.

The experiments were carried out between May and June 2020, after months of obligatory use of surgical masks, social deprivation, existential threat and uncertainty which altogether might have altered emotional experience and expression due to known increase in mental illnesses and disorders [189,190]. It is important to underline that recent findings suggest that isolation and physical distancing itself - which has been misinterpreted by mainstream media as social distancing - may also be responsible for functional uncertainty, as it is associated with neuropsychological and neurobiological changes in early childhood and with age [191], and therefore may alter nonverbal communication patterns.

Further and better funded investigation involving artificial intelligence that enables temporal data processing – eg: emotional Saturation and Transparency – in a larger sample may also be required to determine whether and how metacognitive abilities interplay in the expression of facial emotions and recognition, especially in relation with psychophysiological correlates – eg. heart rate variability, galvanic skin resistance – of emotion production, empathetic skills and manipulation.” [17]

6. CONCLUSIONS

Our results indicate that the psychological explanations of the Dunning-Kruger paradigm regarding metacognition are correct and remind us that challenging, or even depreciating scientific results based on intentionally designed mathematical models are sometimes nothing but throwing the baby out with the water, although may improve research design and lead to stronger conclusions.

We have found strong links between baseline cognitive performance, metacognitive effectiveness—measured in metamemory performance and decisional awareness—and self-assessment, which deviated the most from default after the initial shock in men and women of four generations during the COVID-19 crisis, however further investigation may be required to define whether the associations are direct or under another, yet hidden influence.

We have confirmed that performance and self-assessment ratings were 1) task dependent and 2) in line with the results of previous investigations (eg: the dual burden effect), now explored in basic cognition. Subjects in general were able to assess their performance compared to each other correctly despite their biases, and since we have also confirmed that both empirical metacognitive indices – metamemory and decisional awareness – correlate with self-assessment, we may safely say that earlier arguments of previous psychological explanations also stand. Separating causes from effects and understanding what, when, how and why certain changes affected individuals during the pandemic are extremely difficult. Although we were able to confirm the decrease in metacognitive effectiveness that we expected on the basis of the increased prevalence of related mental disorders, the exploration of whether and how and to what extent the neural correlates of metamemory are affected by direct exposure to the virus, immunization, or psychosocial discomfort as a result of the control measures requires further investigation.

Sample characteristics allow us to generalize our results to mentally healthy working-age populations with the usual limitations of academic research [192]; hence, the prevention of an increase in psychosocial discomfort and a decline in mental health arising from such synergy of multiple negative events requires more thoughtful communication and improved action preparedness from future crisis managers, both globally and locally.

7. SUMMARY

The main aim of the study was to reveal how self-assessment, personality traits and facial emotional expressions are interrelated, therefore we first have analysed the associations between our main variables then understood how the effects of the historical context – the COVID-19 crisis – affected our sample.

We investigated in line with three hypotheses to reveal how 1) self-assessment bias is associated with metamemory and decisional awareness, 2) how COVID-19 affected sexes and generations to different extents regarding cognitive performance, metacognitive effectiveness and self-assessment in terms of generational and sex differences, and finally to explore 3) how self-confidence (measured in self-assessment bias), personality traits and facial emotional expressions are interrelated.

We recruited a sample (n=1394) of adult, mentally healthy subjects who completed four computerized short-term memory tests of increasing complexity designed to investigate basic cognition, self-assessment and metacognitive abilities. We then eliminated extremely low and high performers, leaving a final sample of 354 subjects who were able to assess their performance equally optimistic or pessimistic on a Likert scale of 6. Then we filtered our original sample based on age (n=1385) to reveal intergenerational and sex differences during the COVID-19 crisis, to understand better the characteristics of our target sample (n=35) who attended a screening of artistic and artificial stimuli, where their facial emotional expressions were recorded and analysed by artificial intelligence.

Cognitive and metacognitive abilities—metamemory and decisional awareness—and self-assessment are associated with each other as hypothesised and results confirm our third hypothesis regarding "self-assessment bias in association with emotional expressivity – neutrality, saturation, transparency – and the display of anger and hostility. Our results indicate that self-assessment bias interplays in subconscious communication with empathetic skills and manipulation." [17] The significant associations between self-assessment bias, performance, decisional awareness and metamemory provides clear evidence that self-assessment has a strong metacognitive faculty and without any feedback during the tests, involves intuitive processes and strongly associated with empathetic skills.

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9. BIBLIOGRAPHY OF PUBLICATIONS

9.1.1. Publications related to the thesis:

Kasek, R., Sepsi, E. & Lázár, I. (2025). Overconfident, but angry at least. AI-Based investigation of facial emotional expressions and self-assessment bias in human adults. BMC psychology, 13(1), 1-9.; https://doi.org/10.1186/s40359-025-02590-7; PMid:40065465 PMCid:PMC11895137 IF: 3.0

Kasek, R., Sepsi, E. & Lázár , I. (2024). Teljesítmény, magabiztosság és mimika: az arcon megjelenő érzelem-kifejezés és a metakognitív képességek vizsgálata *In: Lázár Imre (szerk.) Sorsunk hálóiban: Szocioszomatikus hálózatok nyomában* Budapest, Magyarország: L'Harmattan Kiadó, Károli Gáspár Református Egyetem, pp. 257-269.

Bozsányi, S., Czurkó, N., Becske, M., Kasek, R., Lázár, B. K., Boostani, M., ... & Lázár, I. (2023). Assessment of Frontal Hemispherical Lateralization in Plaque Psoriasis and Atopic Dermatitis. *Journal of Clinical Medicine*, *12*(13), 4194. IF:3.0

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9.1.2. Publications not related to the thesis:

Sepsi, E., Kasek, R. & Lázár, I. (2021). Művészeti befogadás pszichofiziológiai vizsgálata Noldus FaceReader8 segítségével. *Károli Gáspár Református Egyetem L'Harmattan Kiadó,* Budapest, pp 212-230.

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