CONTEXTualized
emotion bioregulation training for professionals and youth at risk

Contents

Project proposal

Theme
Emotion regulation and the brain: individual differences and societal relevance

1. General project information

Title of the project*
CONTEXTualized emotion bioregulation training for professionals and youth at risk

Main applicant					
First name, surname, title(s)	*Organisation*	*Appointment*	*Position*	*End date contract*	*Expertise (in key words)*
Dr. Floris Klumpers	Radboud University (RU)	Tenured (indefinite)	Associate professor	Indefinite	Psychophysiology, affective neuroscience, virtual reality biofeedback in police

Co-applicant(s)					
First name, surname, title(s)	*Organisation/ host country*	*Appointment*	*Position*	*End date contract*	*Expertise (in key words)*
Dr. Katherine Bassil	UMC Utrecht (UMCU)	Fixed-term	Assistant professor	31/05/2025	Neuroethics, ethics
Prof. dr. Eveline Crone	Erasmus University Rotterdam (EUR)	Tenured (indefinite)	Full professor	indefinite	Developmental Neuroscience, Participatory Action Research
Dr. Willem Frankenhuis	University of Amsterdam (UvA)	Tenured (indefinite)	Associate professor	indefinite	Mathematical modeling, adaptation to stressful environments
Dr. Ilse van de Groep	Erasmus University Rotterdam (EUR)	Fixed-term	Other (please specify): Postdoc	31/05/2027	Developmental Neuroscience, Participatory Action Research
Prof. dr. Erno Hermans	Radboudumc	Tenured (indefinite)	Full professor	indefinite	Cognitive / affective neuroscience, stress-related psychopathology
Dr. Karin Jongsma	UMC Utrecht (UMCU)	Tenured (indefinite)	Associate professor	indefinite	Bioethics, ethics of technology, ethics parallel research
Dr. Florian Krause	Radboudumc	Fixed-term	Other (please specify): Postdoc	31/10/2025	Cognitive Neuroscience, (real-time) neuroimaging,

					neurofeedback, large-scale brain networks, EMA
Prof. dr. Karin Roelofs	Radboud University (RU)	Tenured (indefinite)	Full professor	indefinite	Emotion regulation, Affective Neuroscience, stress-related psychopathology
Dr. Carmen-Silva Sergiou	Amsterdam UMC (AUMC)	Fixed-term	Other (please specify): Postdoc	15-02-2026	Forensic neuroscience, virtual Reality
Dr. Marta Anna Marciniak	Erasmus University Rotterdam (EUR)	Tenure track	Assistant professor	indefinite	Ecological momentary interventions, mobile assessments
Prof. dr. Lucres Nauta-Jansen	Amsterdam UMC (AUMC)	Tenured (indefinite)	Full professor	indefinite	Translational Forensic Child and Adolescent Psychiatry, neurobiology of antisocial behavior in youth
Prof. dr. Annika Smit	University of Humanistic Studies (UvH)	Tenured (indefinite)	Full professor	indefinite	Resilience in police
Dr. Annelinde Vandenbroucke	Amsterdam UMC (AUMC) / University of Applied Sciences Utrecht	Fixed-term	Other (please specify): Postdoc	30/09/2027	Co-creation, youth at risk for aggression Science communication

Cooperation partner(s)[j]				
First name, surname, title(s)	*Organisation / host country*	*Type*	*Sector*	*Expertise (in key words)*
Bas van Tol	Knowledge Center People and Police (GOMM), NL	*Other*	*Other*	Dutch national police
Michiel de Groot	Central Works Council National Police (CWC), NL	*Other*	*Other*	Police officer perspective
André Ditewig	Stichting Innovatie en Zorg (PZP), NL	*Foundation*	*Healthcare*	Police health insurance and police union
Esther Overweter	Young Perspectives (Yope), NL	*NGO*	*Other*	Perspectives of youth in forensic care
Lieke van Domburgh	iHub Zorg BV (iHub), NL	*Business large*	*Healthcare*	Youth care

Janet ten Hoope	Bureau Halt (Halt), NL	*NGO*	*Education*	(Prevention of) criminal behavior in youth
Nellieke de Koning	Levvel, NL	*Business large*	*Healthcare*	Specialized youth care
Prof. dr. Stefan Bogaerts	Fivoor BV (Fivoor), NL	*Business large*	*Healthcare*	Forensic psychiatry
Martijn Janse	Stichting Lieve Mark (SLM), NL	*Foundation*	*Healthcare*	Mental wellbeing and youth participation
Frederieke Vriends	MIND Us, NL	*NGO*	*Healthcare*	Youth mental health
Simone Frederiksz	Albeda MBO (Albeda), NL	*Public knowledge institute*	*Education*	Secondary vocational education
Dr. Frans Spierings	Rotterdam University of Applied Sciences (HR), NL	*Public knowledge institute*	*Education*	Higher education and talent development
Ate Osinga	Arq Centrum '45 (Arq), NL	*Healthcare organisation*	*Healthcare*	Psychotrauma treatment
Wendy Dorrestijn	KMAR, NL	*Other*	*Other*	Marechaussee, first responders
Dave Weerstand	Fyment, NL	*Business SME*	*Education*	Resilience training for security guards
Wim Keizer	Ministry of Defence (MinDef), NL	*Governmental organisation*	*Government*	Military policy, military psychology
Tineke Rengers	Gemeente Emmen (Emmen), NL	*Governmental organisation*	*Government*	Municipality, policy regarding policing, societal violence and health

Co-funder				
First name, surname, title(s)	*Organisation/host country*	*Type*	*Sector*	*Expertise (in key words)*
Leonard Kok	Police Academy (PA), NL	*Public knowledge institute*	*Education*	Police education

Summary of the project budget	
Requested from NWO	€ 6.749.991,-
Contributions co-funders	in cash: € 0,-
	in kind: € 29.616,-
Total project budget	€ 6.779.607,-

2. Problem analysis and impact

Why can some people flexibly regulate their emotional reactions in stressful situations while others resort to rigid fight-or-flight responses? Effective emotion regulation in high-stress contexts is critical for successfully navigating many challenges in society, whether at the level of individuals, social groups, power dynamics, or politics. This is especially important for groups frequently exposed to stressful, often violent, encounters with far-reaching consequences. **Improving emotion regulation in these at-risk groups holds promise to significantly enhance both individual well-being and societal safety**. CONTEXT focuses on two groups at high risk due to their regular exposure to acute stress, that frequently face each other in direct confrontations: *rule-breaking youth* and *rule-keeping police professionals*. Although often cast as adversaries, these groups are essentially peers—young adults facing similar challenges during stressful confrontations. Current approaches to enhancing emotion regulation in such scenarios, however, remain inadequate. **Existing theories overemphasize emotional downregulation.** They moreover **lack a mechanistic account** of how physiological (autonomic nervous system) and neurocognitive (emotion regulation) changes interact during acute stress, **limiting the ability to flexibly and contextually regulate emotions**. Consequently, **current interventions designed to improve emotion regulation are ineffective in high-stress situations**. CONTEXT addresses these problems by bringing together a unique interdisciplinary consortium to: 1) develop a novel descriptive model of context-appropriate flexible emotion regulation in stressful situations, 2) uncover the interactions between the central and autonomic nervous systems that drive emotion regulation and individual differences in aggression during acute stress, and 3) leverage **groundbreaking innovative techniques** to develop **a neurobiologically grounded, contextualized, gamified, and scalable dual-loop biofeedback training**. This training will be co-designed with both police professionals and at-risk youth to help them manage their emotions when it matters most. Ultimately, CONTEXT aims to reduce stress, improve mental health, enhance professional performance, decrease youth aggression and recidivism, and foster stronger social connections.

2.1 Problem analysis

SOCIETAL PROBLEM: Suboptimal emotion control in police and youth impacts societal safety and health

Emotions are evolutionarily prepared action programs that help guide our actions and decisions in situations of great personal relevance[1, 2]. The regulation of emotions becomes essential in situations where prepotent reactions, such as fight-or-flight reactions under threat, are maladaptive and more controlled or instrumental responses are required[3, 4]. Research from our consortium and others unraveled the neuroscientific mechanistic framework that guides individuals towards adaptive emotion regulation, showing that the limbic-prefrontal circuit is well equipped to guide flexible control of our emotions based on environmental demands[5, 6]. **However, in stressful situations, this system is strongly challenged and often fails**[7, 8]. In particular rule-breaking and rule-keeping individuals in our society are exposed to stressors on a daily basis, often followed by

***Box 1:** Glossary of key concepts used in CONTEXT*

Police at risk: Police officers at risk for developing stress-related complaints due to frequent exposure to high-stake, stressful situations.

Youth at risk: Youth with a history of police contact due to rule-breaking behavior in the age range 16-24 years.

Emotions: States that combine psychophysiological and visceral responses with subjective and behavioral components such as action tendencies. They contain evolutionary prepared action programs that help guide our actions and decisions in situations of great personal relevance.

Flexible emotion regulation: The ability to implement emotion regulation strategies that are synchronized with individual and contextual demands (e.g., short- and long-term goals, situational context, individual traits).

Participatory Action Research (PAR): Scientific approach grounded in principles of equity, engaging people in identifying problems relevant to their own lives, conducting research to understand the problems, and advocating for changes based on evidence.

Biofeedback: Real-time feedback about physiological signals (e.g., heart rate variability) used to train individuals to become aware of and control their physiological responses.

Autonomic balance: the balance between activation in the sympathetic and parasympathetic branches of the autonomic nervous system (ANS).

Ecological Momentary Assessment (EMA): Structured self-report method to assess mood, symptoms, context and appraisals thereof in daily life.

Ecological Physiological Assessment (EPA): Repeated physiological measurements via wearable biosensors in daily life.

Just In Time Adaptive Intervention (JITAI): Digital health intervention that monitors physiology in real-time and delivers tailored messages at specific times when need for support is detected.

aggressive encounters. This creates an urgent need to better understand the mechanisms of emotion regulation and opportunities for training emotion regulation in these groups: First-responding professionals, especially police in the line of duty, are regularly exposed to intense, potentially traumatic events even when they are still in training[9]. **Each year, up to 92% of first responders report being victims of aggression by members of the public** - the majority even on a monthly basis (police.nl). Inadequate control of emotional responses in acutely stressful situations such as these is not only predictive of long-term stress-related mental health problems in police[9, 10], but also a leading cause of inappropriate violent behavior[11-13]. The societal relevance of this is further emphasized by recent reports of an increase of over 50% in excessive police violence since 2021 in the Netherlands (police.nl).

Not only professional rule-keepers (police), but also rule-breaking individuals suffer from stressful confrontations in daily life. Most violent offenses are committed by youth aged 12-23 (cbs.nl). Despite general declines in overall offense rates, **serious violent crimes among youth have even been rising recently** (wodc.nl). **At the same time, youth in the age group 15-25 are also most frequently the victims of violence** (ocw.nl). Research from our consortium previously demonstrated that emotion regulation is still developing in adolescence and young adulthood, and particularly challenging for those who show rule-breaking behavior [14].

It is particularly relevant to investigate young offenders and police in training within one research program because they are not only adversaries during conflicts, but they are often of similar ages (late adolescence / early adulthood) and backgrounds, and it has been hardly recognized that not only youth but also police officers in training need to rely on developing emotion regulation skills. Police and youth indeed both have known difficulties in regulating emotions[15, 16]. This may well reflect similar neurobiological mechanisms, yet to date no studies have been able to compare neural mechanisms of emotion regulation in the two social groups who most often encounter each other in stressful and violent situations.

The consequences of violent confrontations between professionals and youth are far-reaching, both at the individual and societal level. Beyond direct physical harm, law enforcement officers often experience increased mental health problems, long-lasting declines in morale and higher dropout rates as common consequences[10, 13]. For youth, even a single confrontation with the police can be a life-changing experience. Confrontations have been documented to lead to severe emotional distress, mental health problems, loss of future opportunities due to stagnation of education, stigmatization, recidivism and further radicalization[17-19]. At the societal level, violent confrontations alone result in hundreds of millions of euros lost due to professionals being unable to perform their duties effectively (tno.nl). For youth, the costs may be even higher, as the impact on lifelong functioning can persist over time. Beyond financial costs, such confrontations are rapidly highlighted in today's (social) media[20]. As such, direct and vicarious experiences of confrontations significantly affect perceptions of societal safety, by amplifying stress and worry about future confrontations and anticipated associated negative consequences[21]. This leads to further polarization and two-way stigmatization between youth and law enforcement[22].

STAKEHOLDER PERSPECTIVE: High stakes and lack of adequate interventions to improve emotion regulation

Understanding complex societal challenges with research methods that cross the boundaries of individual scientific disciplines requires a transdisciplinary approach with involvement of stakeholders in every step of the design. This includes human centered design, where stakeholders (e.g. professionals) provide input on their needs for a successful intervention. It also includes participatory action research (PAR)[23], where stakeholders (e.g. police/youth) are leading the research questions in a participatory manner such that their input is used towards societal action. In line with the principles of co-design and our participatory action approach, **CONTEXT has —in preparation for this application and based on our existing connections with key stakeholders— canvassed the experienced problems** related to the regulation of emotion in small groups of police, youth and (forensic) youth experts (N = 6-8 per group; see Table 1).

Analysis of this input reveals **three shared causes of the societal problem**: (I) youth and professionals **struggle to effectively apply emotion regulation** strategies**,** especially in high-stress situations[15, 16]; (II) current emotion regulation interventions are **insufficiently appealing / motivating and not connected to real-world situations,** leading to limited efficacy[24-27] and high drop-out rates[24, 28]; and (III) s**tigma around discussing negative emotions and seeking help** hinders the recognition and management of negative effects in these groups[29, 30].

Table 1: *Summary of collected input from stakeholders regarding problems with emotion regulation and excessive violence*

Stakeholder	Identified pressing problems related to suboptimal emotion regulation under stress and increased violence	Source
Police academy trainers and knowledge brokers	Existing stress resilience *measurements* are subjective/not concrete. Emotion regulation and stress resilience *interventions* are not empirically supported; not appealing/motivating; suffer from a stigma (talking about negative emotions and seeking help for this); lack connection with real-life stressful situations.	Interviews
Police organization	Increased societal hardening and polarization in society. Lack of training in dealing with aggression. Extreme pressure under which decisions are typically taken due to increased severe violence against police	Surveys & publications (police.nl)(police.nl)
Youth (aged 16-23)	Youth indicate loss of control over their emotional responses, including freezing and aggression, during stressful encounters. Youth (at risk) lack accessible strategies and practical tools to deal with stress and negative emotions quickly (preferring quick and enjoyable solutions).	Interviews
Forensic social work professionals	Need for effective strategies or tools to reduce the lack of trust and to deal with unwillingness to talk about emotional issues in treatment/help for youth at risk. Need for reflection and a safe work environment to show and share emotions.	Interviews
Youth workers	Limited time and resources to support emotion regulation of youth in a personalized manner. Lack of scalable and accessible solutions that allow for support of youth outside of the traditional therapy/meeting sessions.	Interviews

CONTEXT aims to improve societal safety and health by leveraging theoretical and methodological innovations to develop and implement a neurobiologically inspired, effective emotion regulation training for professionals and youth at risk

SCIENTIFIC PROBLEMS hampering the development of effective emotion regulation training: CONTEXT matters

How can we develop an attractive intervention for these target groups that effectively aids emotion regulation through state-of-the-art neuroscience insights? There are three main knowledge gaps (KGs) related to the contextual embedding of emotion regulation in interventions.

KG1: One-sided focus on downregulation of emotion. Traditional neurocognitive theories of emotion regulation[3, 31] implicitly assume that adaptive behavior is defined by the ability to **attenuate emotional responses**. Consequently, these neural theories have disproportionately focused on top-down control mechanisms, particularly emphasizing prefrontal cortex-driven downregulation of amygdala-mediated responses, such as fight-or-flight[4, 32, 33]. While downregulation may be desirable from a social and cultural perspective, **these models overlook the importance of the evolutionarily shaped repertoire of emotional responses, which allows humans to rapidly switch between low- and high-arousal autonomic states to facilitate corresponding actions based on contextual demands.** For instance, in some high-stress situations, adequate responding by police officers requires not downregulation but elevation of arousal[34]. Furthermore, a recent review and meta-analysis in over 800 youth by CONTEXT partners confirmed that individual differences in reactive versus proactive aggression are linked to variation in autonomic arousal, indicating the relevance of not only high arousal but also hypoarousal states to aggression[35, 36]. The lack of conceptualization in existing theories, particularly regarding which contexts require which specific forms of regulation in which individuals[37-39], hinders progress in improving emotional control. CONTEXT will address this gap by moving away from normative theories focused solely on downregulation **toward a novel, descriptive model of emotion regulation** in stressful situations. In addition, we will model **real-life contextual and emotional dynamics** acquired through uniquely integrated ecological momentary assessments of contextual demands, subjective experiences, physiological states, and corresponding actions. The resulting knowledge on situational and individual differences is essential to develop a novel neurocognitive model of flexible emotion regulation under high-stress conditions (KG2) and translate this into effective and usable interventions (KG3).

KG2: Lack of mechanistic neurocognitive understanding. Cognitive neuroscience has significantly enhanced our understanding of the neural underpinnings of various emotion regulation strategies, including cognitive reappraisal, emotional suppression, distraction, and mindfulness[40, 41]. In recent years, CONTEXT consortium partners have contributed groundbreaking insights into **how our brains enable flexible shifting between emotion regulation strategies**. This research highlights the role of specific prefrontal cortex regions in monitoring

the efficacy of current and alternative options, as well as integrating emotional and context-dependent goal information from other neural regions[5, 6, 42] (Figure 1, Box 2). However, other influential work by consortium members has demonstrated that **the effectiveness of frontal integrative functions is impaired under high-stress conditions** marked by arousal in the autonomic nervous system (ANS)[7, 8]. There is great individual and situational variation in balance in ANS arousal under stress, whereby sympathetic dominance impacts the central nervous system (CNS) and emotional behavior very differently from parasympathetic dominance. **It remains unclear how the integration of emotion and context-dependent goal information fails during stress-induced imbalances in autonomic nervous system activation**[5, 43] (Box 2). Furthermore, there is a pressing need to understand how individual differences in autonomic balance shifts under stress impact the neural mechanisms underlying flexible emotion regulation. CONTEXT will address this by **investigating CNS-ANS interactions**, assessing concurrent activation in both the sympathetic and parasympathetic branches of the autonomic nervous system, and testing the **impact of autonomic balance on the neural functions** that underlie flexible emotional control in individuals.

KG3: Current interventions for training emotion regulation are inadequate in high-stress conflict situations. First, due to the predominant focus on cognitive downregulation of emotions, commonly used approaches—e.g. reappraisal training, mindfulness-based cognitive therapy, and cognitive distraction techniques—primarily aim to enhance **the ability to cognitively regulate emotional states**. While effective in mitigating for instance internalizing symptoms in relatively low-arousal contexts, **these techniques disregard the requirement to flexibly apply a broader range of emotion regulation strategies, which is essential for adaptive behavior in high-stress conflict scenarios**[6]. Second, traditional interventions draw on neurocognitive systems that are typically impaired in high-stress situations. CONTEXT proposes that specific states of autonomic nervous system activation can effectively determine which circuits for control of emotions and emotional action become dominant. Consequently, **maintaining autonomic balance** (Box 2) **is a critical prerequisite for preserving flexibility in emotion regulation**. Interventions aimed at enhancing this flexibility should also **focus on sustaining autonomic balance**. Such interventions should bypass neurocognitive functions that are compromised under stress by teaching individuals strategies through biofeedback[44, 45]. Third, traditional interventions are practiced in calm, relatively unstimulating contexts without direct objective feedback. This limits transfer to situations of high acute stress, while fundamental theories of learning and memory emphasize the importance of alignment between learning and retrieval contexts to aid subsequent recall[46, 47]. This alignment of the learning situation with the actual application context is even more important when it comes to skills to be applied in stressful situations, as stress typically impairs recall[48, 49]. Finally, to achieve true behavioral change, **it is essential that interventions are carefully tailored to the needs and interests of target groups**, as motivation is a strong predictor of intervention success. This highlights the importance of appealing co-designed interventions[50, 51].

To address these key issues, CONTEXT will develop a novel biofeedback training program designed to **enhance the ability to maintain balanced activation of the sympathetic and parasympathetic branches of the autonomic nervous system**. Building on the previous work on biofeedback of consortium members[44, 45, 52-54], our goal is to train control over this balance by providing continuous feedback on psychophysiological indicators of (para)sympathetic activation, such as heart rate frequency and variability (HRV), which participants are trained to control using strategies (e.g. breathing exercises) that are easily transferrable to high-stress situations. CONTEXT will introduce three critical innovations to existing biofeedback approaches. First, we will focus on **training flexible emotion regulation skills in high-arousal situations**, rather than in isolated, passive contexts that lack real-world relevance. To create an ecologically valid training environment, we will employ a virtual reality-based, gamified system, supported by a closed-loop feedback mechanism. In this system, changes in physiological parameters are fed back to the trainee through sensory features within the virtual environment[44, 45, 52, 55] (Figure 2). The second key innovation is **anchoring and boosting the training in real life**[56]. This will be achieved by reinforcing learned behaviors with a second feedback loop, helping individuals to recognize stressful moments in their daily lives when these skills need to be applied. This approach will build on consortium members' work on just-in-time adaptive interventions that are triggered by real-time psychophysiological data. **This dual-loop training setup enhances real-life interoceptive awareness of autonomic states, enabling optimal transfer of skills to real-world high-stress situations**.

Box 2: *Functional neurobiology of flexible emotion regulation (and its failure when stakes are high)*
A key psychobiological foundation of acute emotional responding is the **autonomic nervous system (ANS)**. This system enables fast defensive physiological responses in the face of perceived threats to our wellbeing, making it a central mediator of behavioral reactions to threats[43, 57]. With **norepeniphrine (NE)** as its main

neurotransmitter, the sympathetic branch of the ANS boosts arousal and leads to tonic elevations in heart rate that enable fast fight/flight. In contrast, with **acetylcholine (ACh)** as main neurotransmitter, the parasympathetic branch is essential for variability in heart rate (HRV) and for flexible responding in situations where the appropriate action is not immediately clear[42, 43].

While traditional neurocognitive theories of emotion regulation emphasize the role of top-down control in dampening excessive emotional responses, such as fight/flight reactions[3, 4, 33], recent theoretical work has outlined the neural mechanisms involved in the flexible adaptation of psychophysiological states to meet action goals and contextual demands [7, 8, 58, 59]. This flexibility is crucial for integrating ascending emotional information from the ANS with action goals, monitoring the effectiveness of ongoing and alternative emotion regulation strategies and, ultimately, regulating the balance between sympathetic and parasympathetic arousal systems to dampen excessive emotional responses (Figure 1).

In high-stakes, stressful contexts, flexible emotion control is reduced due to increased sympathetic nervous system activity. This increase in sympathetic arousal leads to a surge of norepinephrine and dopamine that acutely impacts prefrontal function[60, 61], predominantly resulting in fight-or-flight responses and more impulsive and error-prone decision-making[62], even in police trained to deal with stress[11, 63, 64]. Thus, the neurobiological sequelae of acute **stress can create a vicious cycle** where more stress leads to reduced flexibility and impaired emotion regulation, reducing context-adaptive controlled emotional behavior. Interventions should thus aim at storing autonomic balance, thereby optimizing context-dependent ANS-CNS interactions.

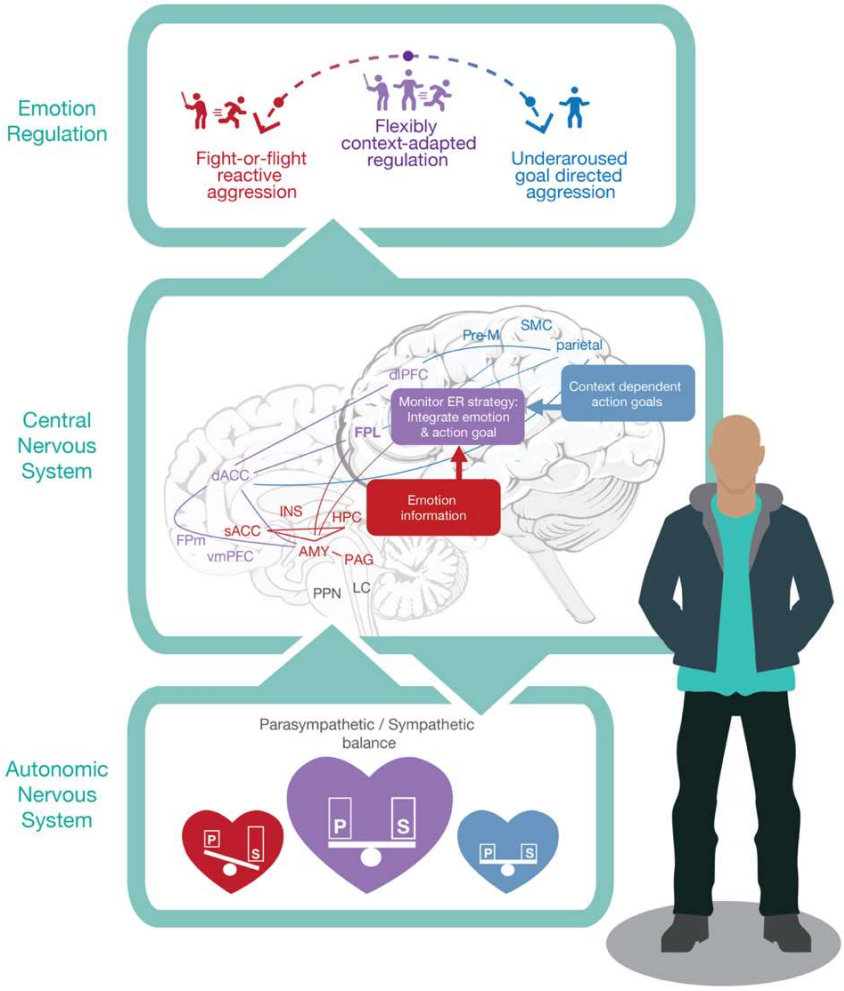

Figure 1: *Neurobiological model of individual differences in emotion regulation. Core central nervous system (CNS) regions of the prefrontal executive control network (purple structures) play an important role in integrating information about emotional states from the salience network (red regions) with action goals (blue regions) while monitoring the effectiveness of current and alternative emotion regulation strategies. In addition, these structures provide top-down regulation of the balance between sympathetic and para-sympathetic arousal systems. However, when stress levels rise, flexible emotion control via the purple network fails due to disbalance in the para /sympathetic components of the autonomic nervous system (ANS). Such disbalance can involve overactivation in the sympathetic system associated with rapid fight-or-flight responses (red heart),but can also involve underactivation in the sympathetic (and para-sympathetic) system, impairing affective processing (blue heart). Optimal flexibility is supported by co-activation of the sympathetic and parasympathetic nervous system (purple heart)* [5,6]

2.2 Assumptions in the problem analysis

1. **Improving emotion regulation in stressful situations will benefit professionals and youth at risk and thereby societal health and safety.** This central assumption will be rigorously evaluated in the current project as indicated in the impact pathway and work description below.
2. **The pressing problems identified by the stakeholder interviews are representative for their peer groups.** This assumption will be verified in the initial phase of the project through focus groups with representative groups from our target populations as well as meetings with the stakeholders.
3. **Flexible emotion regulation requires individually dependent balancing of sympathetic and parasympathetic nervous systems**. This assumption is based on recent theories put forward by our consortium regarding the essential role of the ANS in determining CNS balance[5, 43, 57] supported by recent empirical work in police[42, 64], combined with recent insights regarding the pathophysiology of individual differences in aggression in youth[35, 36]. CONTEXT will be the first to rigorously test this hypothesis causally.

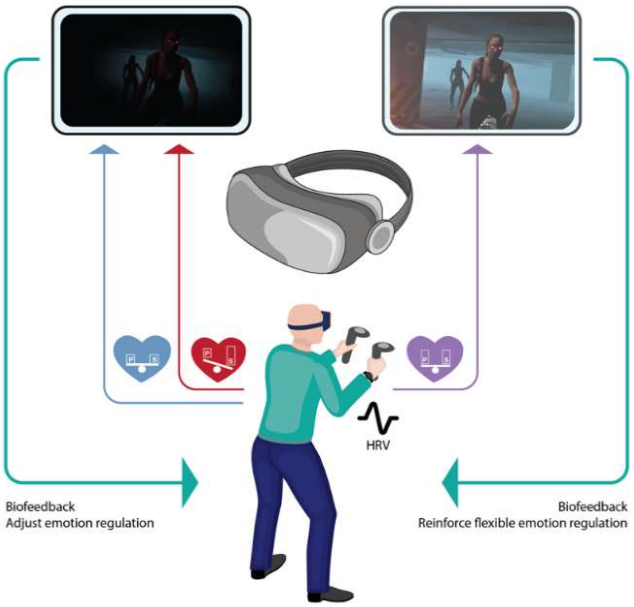

Figure 2. *Closed loop gamified virtual reality (VR) setup to train autonomic balance awareness and control. Information on subjects' autonomic balance measured by heart frequency and variability (HRV) is directly fed back to participants in a closed loop circuit by impactful changes in gameplay (e.g. in this case change in visibility of the game). Pilot work by the CONTEXT members, demonstrate not only that this training is highly engaging but also allows for successful control over ANS balance that transfers to real-life situations[44,52].*

4. **Individual differences in emotion regulation can be traced back to and causally manipulated by neurobiological mechanisms.** There is ample correlational support for this assumption from literature[9, 33, 64], but well-powered studies required to uncover the typically small effect sizes associated with individual differences are scarce. Our program builds on previous large datasets assembled by the consortium[9, 35] to verify and test this further in these two target groups of exceptional societal relevance.
5. **The neurobiological processes that support emotion regulation are highly individual but at a basic level similar in police and youth at risk.** This assumption is supported by existing separate literature on youth at risk and police. Our ability to directly test this holds promise not only for knowledge exchange between traditionally separated research fields (with potential implications for prevention) but also for boosting mutual understanding and to reduce mutual stigmatization.

2.3 Societal impact

CONTEXT will contribute to a safer and healthier society via the direct impact of a new intervention for **improving emotion regulation in police officers and youth at risk for being involved in violent encounters**. Ultimately, improved flexible emotion regulation will lead to changes that range from the individual to the societal level:

Lower stress levels, better (mental) health - Our intervention builds on recent insights that emotion control and autonomic balance in the moment of acutely stressful situations are key mechanistic predictors of long term resilience to stress both in police and youth at risk[9, 65, 66]. These findings support our expectation that our intervention leads to reduction in daily-life stress, ultimately improving mental health. Estimates indicate that up to 30% of police suffer from (clinical or subclinical) traumatic stress symptoms. It has been shown that for youth within forensic institution, prevalence of cumulative trauma is about 40%[67], while prevalence of post-traumatic stress disorder in this population is estimated at almost 9%[68].

Improved performance in stressful situations in professionals at risk - The high levels of exposure to extreme stressful events is known to severely impact police performance despite their extensive training[13, 63]. Documented reductions in emotion control during stress[64] can have devastating consequences on performance, leading to impairments in decision making and in some cases excessive violence[11, 13]. While documented cases

of excessive police violence are rare, they have a profound impact on society especially also because they more often affect minority groups that are more vulnerable to its consequences[17]. During and after the project, we will explore expansion of emotion regulation training to other at-risk professionals (longer-term impact), including via the representatives from e.g. military, military police, and security guards in our Stakeholder Forum.

Decreases in aggression and (re-)offending rates for youth at risk - Decreased aggression in youth will not only decrease psychological damage for victims and financial costs associated with violence (related to legal processing and healthcare) but will also reduce societal unrest. In addition, it will increase mental health and decrease recidivism for these youth. Per year, approximately 20.000 youth and young adults (12-23 years) are reported by the police as suspect of aggression-related crime (youthmonitor.nl). Moreover, how police encounters are perceived by youth, in terms of violence and justness, is related to re-offending rate[19]. Our interventions are therefore expected to lead to a reduction in aggression and offending rates for youth.

Increased social connection and reduced polarization - With our training, we aim to reduce conflict between our target groups. Because of the strong negative impact of violence on social groups and mutual negative perceptions by youth at risk and police, better emotion regulation can help improve mutual understanding between youth at risk and police. CONTEXT will seek direct proof of concept by investigating and training real-life interaction between youth and police.

2.4 Relationship with the objective of the Call and the relevant theme

2.4.1. General objectives of the NWA-ORC call

Scientifically pioneering - CONTEXT will provide fundamental insights in autonomic nervous system regulation during real-life acute stress situations and demonstrate the neurocognitive underpinnings of how automatic emotional reactions are flexibly regulated. To do so, it integrates the newest insights into flexible decision making and context-dependent adaptation relevant for flexible emotion regulation. CONTEXT is groundbreaking not only in its conceptual innovations but also in the techniques it will develop: it leverages technical innovations in real-time closed-loop VR biofeedback and closed-loop just-in-time interventions using wearables. These techniques will be combined to meet the requirements of different target groups for skill transfer from training to real life. The so-called dual loop training is a novel concept[53] in which the self-regulation skill is learned in a immersive context and then trained in real life, via real-time closed loop systems where the actual psychophysiological states affect the training tool (VR-environment in the first loop and wearable-guided actions in the second loop).

Active involvement of citizens - Both police professionals (officers in blue; police leaders; recruits; educational specialists; police trainers; technical support staff) and youth (youth that have shown previous rule-breaking behavior - including those that committed minor offenses and those in forensic institutions; youth workers; youth (forensic) care professionals; teachers) are actively involved in the co-design of our proposed solutions. CONTEXT combines participatory action research (PAR) with experimental neuroscience, focusing on both police and youth. CONTEXT pioneers bringing together police and youth in 'experiential programs' designed to prevent stigmatization and to promote active engagement and communication via shared experiences.

Relevant and full of impact for society - Our interdisciplinary research program will deliver novel interventions and educational modules that can be applied in police education and youth institution programs right away. CONTEXT outputs thus hold great promise to improve emotion regulation in youth and police in daily life, leading to a decrease in stress-related health problems and aggression (see Section 2.3).

Knowledge chain wide - The applicants and co-funding partner include researchers from a diversity of organizations: universities, university medical centers, and a public knowledge institute. In collaboration with our diverse stakeholder group, this will facilitate both scientific and societal breakthroughs.

Inter- and transdisciplinary research - CONTEXT combines a diverse range of scientific disciplines: cognitive neuroscience and affective neuroscience, clinical and developmental psychology, psychophysiology, psychiatry, computational modeling, mathematical modeling, and bioethics. In addition, the consortium includes many societal stakeholders representing first responders, including police, military police and military psychology; youth (forensic) care and youth participation organizations; education, including MBO and HBO; policy makers; and mental health care organizations. This shows the broad support and high need for this novel type of scientifically grounded, engaging, and effective interventions.

Productive interactions - To achieve our ambitious goals, all consortium partners as well as the wider Stakeholder Forum are actively involved in all phases of the research process: from formulating the research questions to elaborating the approach to answer these questions and realizing the desired scientific and societal

breakthroughs (also see Section 5.2). Stakeholders have expressed their eagerness to be involved and to actively contribute their perspectives on the goals, vision, and results of the project.

2.4.2. Theme: Emotion regulation and the brain: individual differences and societal relevance

CONTEXT relates to the NWA-ORC theme on emotion regulation in several groundbreaking ways:

Connection between basic neuroscientific principles and individual differences in emotion regulation - CONTEXT will study fundamental aspects of CNS-ANS interactions, uncover distinct profiles in CNS-ANS balance and will directly link those to individual differences in aggressive manifestations. In addition, CONTEXT will provide novel insights into context dependency of emotion regulation and how individual differences in flexible adjustment to context changes are linked to individual differences in aggressive manifestations.

Relevance for mental and/or physical health, behavioral factors related to a safe society, and/or optimizing cognitive functioning e.g. via education - CONTEXT will significantly contribute to improved mental health. The CONTEXT intervention aims to prevent autonomic disbalance and maladaptive responding which is beneficial for mental health. Just in time adaptive interventions hold the promise to promote safety, aiming to reduce confrontations between police and youth at risk. Safety will also be directly addressed by unique experiential interventions where youth and police engage in communication based on shared experiences in the 'police at work workplace'. CONTEXT will directly work towards implementing engaging interventions into educational systems at the Police Academy and in (forensic) youth care. We have ample experience in collaborating with educationalists to implement novel interventions into educational and youth care programs.

Knowledge used for individualized diagnostics and treatment - CONTEXT will directly contribute to preventing undesirable impulsive aggressive behavior. CONTEXT works towards personalized just in time adaptive interventions in the real world, directly optimizing emotion regulation in individuals.

Clear fundamental research component with theoretical implications - CONTEXT will develop an integrated neural model for how the brain adapts emotion regulation to changing contextual demands. It will define individual differences in CNS-ANS patterns that are linked to various aggressive and impulsive manifestations. With a clear focus on how neural networks change their function under acute stress, and how this impacts flexible adjustment to contextual demands, and hence emotion regulation, CONTEXT will not only offer novel empirical insights. It will also define a new theory on contextualized emotion regulation. We will use theoretical and formal modeling combined with empirical research to validate the model and to ensure development of neurocognitive grounded interventions that act where and when they should.

CONTEXT relates to the following NWA cluster questions: **082 - How does the central nervous system develop and how can we counteract degeneration processes in that system?** CONTEXT provides direct insights into how the CNS develops, with a focus on emotion regulation capacities. CONTEXT proposes that groundbreaking new insights can be gained by studying CNS function in direct connection with the autonomic nervous system (ANS). **058 - What are the patterns and causes of crime and how can we influence them?** CONTEXT provides direct insight into neurocognitive risk factors in youth at risk for rule-breaking behavior. A unique feat of CONTEXT is that it also investigates factors that contribute to excessive use of force in police. **083 - How do neurological, psychiatric, and mental disorders arise, and how can we prevent, mitigate, or cure them?** CONTEXT provides direct insight into neurocognitive and -affective risk factors for aggression-related mental disorders and stress-related (mental) health problems. The project will focus on targetable neurocognitive emotion regulation mechanisms to develop interventions that are sensitive to contextual demands and provide direct proof of concept of the effectiveness of the dual-loop intervention. **112: Can we use Big Data and Big Data collection to define values, generate insights, and get answers?** CONTEXT is dedicated to open science and plans to make datasets & analytical tools openly available so that they may combined with other existing datasets for mega analyses that can go beyond the questions answered in the current project.

3. Route to impact

3.1Outcomes

CONTEXT will have clear **scientific outcomes.** The international scientific community builds on the models and theories from CONTEXT regarding individual differences in emotion regulation under stress (**outcome 1**); and builds on the revolutionary dual-loop biofeedback intervention developed by CONTEXT (**outcome 2**).

Societal outcomes will be based on CONTEXT results and with the confirmed support of our stakeholders;

- The Police Academy integrates CONTEXT training in the standard curriculum of the OVDP (Officier van Dienst Politie; an advanced training program that focuses strongly on stress resilience) (**outcome 4**); in the curriculum for the bachelor police (**outcome 5**); in the basic national police training (**outcome 6**); as (booster) training for active serving police to (re-)train (**outcome 7**).
- Bureau Halt, Levvel, iHUB, Fivoor, YOPE, and similar (forensic) youth services implement CONTEXT training as part of their programs (**outcome 8**).
- Police and youth at risk become aware of mechanisms of emotion regulation in stressful situations, both regarding themselves and for the "opposing" group (**outcome 9**) .
- Stakeholders developing policy (police and other first responder organizations, (forensic) youth care organizations, educational institutes, municipalities, ministries, and health insurers) are aware of individual differences in emotion regulation and take steps towards future implementation in policy (**outcome 10**)**.**

3.2 Output

- Novel theoretical and empirical insights regarding the neural underpinnings of (individual differences in) emotion regulation under stress
- Engaging and arousing VR biofeedback trainings (for police and youth) to train flexible emotion regulation
- Insights in how to tailor VR biofeedback training to different individuals in the target groups
- Novel insights on (individual differences in) real-life stress dynamics and physiological aspects related to emotion regulation
- Advanced algorithms to determine optimal timing of just in time adaptive interventions based on wearables
- Engaging and context-based Ecological Momentary Interventions (for police and youth) to train flexible emotion regulation
- An ethics framework for responsible development and implementation of biofeedback technology for emotion regulation in specific target groups
- Formal models to better understand the adaptive benefits and costs of higher and lower levels of emotion regulation, depending on individual characteristics and environmental context
- Novel interdisciplinary theory on optimal emotion regulation
- A co-designed roadmap towards future implementation of emotion regulation training in police and youth
- Educational and psychoeducation modules for Police Academy teachers and youth care workers
- Knowledge clips, podcasts, and lectures on emotion regulation in professionals and youth at risk for knowledge transfer of the results of CONTEXT to stakeholders and the general public

3.3 Assumptions in Impact Pathway

The police academy supports implementation of CONTEXT training. To ensure effective integration of the CONTEXT training we will provide educational modules as a psychoeducational wrapping of the training. This will ensure that our police partners have the essential tools and background to perform the training in the varied groups mentioned above. However, given the breadth of our proposed impact on different aspects of the police curriculum it is essential that the implementation is supported throughout different layers of the organization. Beyond the co-funding by the Police Academy based on the longstanding collaboration with CONTEXT partners, this is aided by the declared support from the National Police, the Central Works Council and the police health care organization and union (PZP).

Youth care organizations support implementation of CONTEXT training. Our contacts with organizations such as YOPE, Bureau Halt and youth care institutions have indicated that there is an urgent need for appealing interventions, specifically for youth at risk. This need, together with stakeholder commitment and long-standing collaborations with CONTEX applicants substantially improve the feasibility of future implementation, for example by making it possible that youth forensic care workers at YOPE, Bureau Halt and youth care institutions can use development hours to receive psychoeducation on the educational modules.

Our target groups will profit from CONTEXT training. To achieve the extensive impact of our training as outlined above, it is essential to not only have support from organization where the training is implemented but also from the target groups. Based on our previous work on co-designed gamified biofeedback interventions we expect that target groups will have considerably higher motivation to use this intervention than other available interventions. This is supported by the use of a participatory action research[23], the gamification element[50], and use of contextually-relevant scenarios that make the VR training more connected to daily life experiences[69].

4. Consortium and productive interactions

4.1 Consortium

The multidisciplinary CONTEXT consortium consists of a strong mix of scientific and societal partners across the knowledge chain, who have contributed to the co-design of this proposal.

4.1.1. Applicants

CONTEXT unites 14 researchers with uniquely complementary expertise, together representing 4 universities and 3 university medical centers (Box 3). They are international leaders in their respective fields of cognitive and affective neuroscience, clinical and developmental psychology, neurobiology, psychiatry, computational modeling, mathematical modeling, dynamic modeling of resilience and bioethics.

CONTEXT consortium members have a proven ability to lead and inspire large research teams. This is exemplified by **numerous prestigious grants** obtained (Figure 3), e.g. **personal grants** NWO Spinoza (Crone), ERC Consolidator and Starting (Roelofs, Hermans, Crone), NWO VICI (Roelofs, Hermans, Crone), NWO VIDI (Frankenhuis, Jongsma, Roelofs, Crone), Marie Curie Fellowship (Vandenbroucke)) as well as **prestigious consortium grants,** e.g. NWO Human Capital (Klumpers Roelofs); H2020/Horizon Europe projects DYNAMORE (Hermans, Roelofs) and NextGen (Jongsma), NWO Gravitation projects GUTS (Crone, Nauta-Jansen) and Exposome-NL (Jongsma), and NWA-ORC projects SCIN (Nauta-Jansen, Vandenbroucke), BOOST (Roelofs) and DESTRESS (Hermans);. Furthermore, applicants actively participate in **scientific networks**, including the International Resilience Alliance (INTRESA) (Roelofs, chair, Klumpers, Hermans); Dutch network of stress research (Stress-NL) (Klumpers, Roelofs, advisory board member; Hermans founding board member); Global Stress and Resilience Network (GSRnet) (Hermans and Roelofs steering committee member); and Flux - International Society for Integrative Developmental Cognitive Neuroscience (Crone, president).

Figure 3: *Key personal and collaborative grants awarded to CONTEXT consortium members*

Importantly, applicants are in direct contact with stakeholders and **play leading roles in knowledge utilization and translating their research into societal impact**. For example, Klumpers and Roelofs lead a collaborative initiative with the National Police, health insurance company CZ and game industry partners to develop a VR biofeedback-based intervention to train decision-making under threat; Marciniak received two Swiss grants for optimization and implementation of mobile app-delivered mental health interventions and bringing them to public market; Crone received a collaborative NWA science communication grant for the youth participation platform YoungXperts, integrating the voice of youth in scientific research and has a strategic partnership with Albeda MBO (vocational education); Van de Groep was responsible for the communication and outreach strategy of the Healthy Start program; Nauta-Jansen participates in the Academic Workplace Youth at Risk (AWRj). Leadership in bringing fundamental neuroscientific insights to societally relevant interventions is also evidenced by several **prestigious prizes** (e.g. International Evens science prize for cognitive neuroscience with societal relevance (Roelofs), Ammodo award (Crone)).

Box 3: *Expertise of CONTEXT applicants and their roles in the project*

Dr. Klumpers (Coordinator and lead WP2) is associate professor at the clinical psychology section of the RU and the Donders Center for Cognitive Neuroimaging. There he builds on his expertise on the inter-individual differences in the psychophysiology of emotions to develop innovative interventions. He has led the development of a virtual reality biofeedback intervention that is currently used in police training. From this experience, he will coordinate the project and lead the development and testing of virtual reality training and biofeedback for emotion regulation. **Dr. Bassil** is assistant professor at UMCU and Niels Stensen Fellow at the

Technical University of Munich. She has specific expertise in investigating ethical concerns in neuroscience research and ethics communication among different stakeholders, and will contribute this expertise in WPC and WPD. **Prof. Crone (lead WPB)** is Erasmus Professor of Developmental Neuroscience in Society at EUR and professor of Neurocognitive Developmental Psychology at Leiden University. Her transdisciplinary research focuses on the psychological and neural processes involved in self-regulation and social development, with a special focus on adolescence. She has vast experience in citizen science and co-creation methodologies, which she will use to coordinate alignment with youth throughout the project. **Dr. Frankenhuis (lead WPC)** is associate professor at the Institute for Biodiversity and Ecosystem Dynamics at UvA and senior researcher at the Max Planck Institute for the Study of Crime, Security and Law. His research focuses on the development of cognition and behavior in harsh and unpredictable circumstances. He has expertise in theoretical mathematical modeling of cognition and behavior. He will lead the development of a mathematical theory of adaptive emotion regulation. **Dr. Van de Groep** is a senior postdoc in Crone's lab at EUR. Her research is focused on the psychological and neurobiological mechanisms that give rise to (mal)adaptive social behavior. She has ample experience in working with youth in forensic and other settings, which she will use to contribute to WPB and WPD. **Prof. Hermans (lead WP1)** is full professor of Cognitive Affective Neuroscience at Radboudumc and PI at the Donders Institute for Brain, Cognition, and Behavior. His research group combines functional neuroimaging with endocrine measures, psychophysiology, pharmacological manipulations, genetics, and behavioral experimental paradigms. He will lead the work on unravelling the neural underpinnings of flexible emotion regulation. **Dr. Jongsma** is associate professor in bioethics at UMCU. Her research is focused on neuroethics, digital health, and ethics issues related to patient and public involvement in research. She will contribute her expertise to WPC and WPD. **Dr. Krause** is a senior postdoc in Hermans' lab at Radboudumc. His expertise is in (real-time) neuroimaging, neurofeedback, large-scale brain networks, and ecological momentary assessment. He will contribute this expertise to WP1, investigating the neural underpinnings of flexible emotion regulation, and WP3, developing and testing Just In Time Adaptive Interventions in both police and youth. **Dr. Marciniak (lead WP3)** is assistant professor in the Division of Clinical Psychology at EUR. Her research is focused on digital health, and she has specific expertise in developing mobile ecological momentary interventions in the context of mental health. She will coordinate the development of Just In Time Adaptive Interventions. **Prof. Nauta-Jansen (lead WPD)** is professor of Translational Forensic Child and Adolescent Psychiatry at AUMC. Her research is focused on the neurobiological background of antisocial and disruptive behavior in youth. For this, she directly collaborates with societal and clinical partners such as adolescents, youth care, police, and the Ministry of Justice. She will coordinate activities to boost the societal impact of CONTEXT. **Prof. Roelofs (lead WPA)** is full professor of Experimental Psychopathology at RU. She is also a BIG-registered GZ-psychologist. Roelofs is an expert in psychological and neuroendocrine mechanisms underlying emotion regulation and vulnerability to stress, with a focus on neurocognitive mechanisms of defensive stress responses. Based on her existing fruitful collaborations with the National Police, she will coordinate alignment with police professionals. **Dr. Sergiou** is a senior postdoc in the group of Nauta-Jansen at AUMC. Her research is focused on unravelling neural correlates of high-risk antisocial youth using innovative technologies including VR. She will contribute to WPD and WPB. **Prof. Smit** is endowed professor Resilience in Police at UvH and scientific chair on Resilience at the Dutch Police Academy. Her research focuses on resilience and integrity in relation to wellbeing of the Dutch police force. Her expertise and vast network will be highly valuable for WPA and WPD. **Dr. Vandenbroucke** is program coordinator of the SCIN study in the group of Nauta-Jansen at AUMC, and at the Academic Workplace Youth at Risk (AWRj; a consortium of scientific and societal organizations). She will contribute her expertise in communication and co-creation with youth and other stakeholders especially to WPD and WPB.

We are convinced that not only disciplinary diversity, but also **diversity in terms of gender, age, cultural background, and personality is essential to thrive as a team**. We thus strive for an open and inclusive research community, offering a broad range of role models. The current consortium consists of 10 females and 4 males. It includes international leaders as well as upcoming talents at different career stages. While the senior applicants assume the responsibility to lead the direction of the research program and to consolidate the expertise of those applicants with a temporary contract, CONTEXT explicitly aims to contribute to the career development of our high potential mid-level researchers (assistant professors and postdocs), including via stepped leadership (see Sections 4.3-4.4). Four current consortium members (28%) have a non-Dutch cultural background. We will use our strong international collaborations to attract diverse talents as PhD students and postdocs.

4.1.2. Co-funding and cooperation partners

The CONTEXT consortium includes a range of societal partners that are essential to build towards relevant outcomes and impact. The Dutch **Police Academy** (PA) contributes as a co-funding partner. The PA is responsible

for professional education of (future) police officers in the Netherlands. In addition, the PA develops insights for police practice and education. Cooperation partners include organizations focused on **youth participation** (Yope, SLM), **(forensic) youth care** (Levvel, iHUB, Halt, Fivoor), **police** (GOMM, CWC, PZP) **and other first responders** (KMAR, Fyment, MinDef), (youth) **mental health awareness** (MIND Us, SLM), **health insurance** (PZP), **policymaking** (MinDef, Emmen), **psychotherapy** (Arq), and **education** (HR, Albeda). Their specific contributions to the project are highlighted in Section 5.

4.2 Productive interactions

4.2.1. Stakeholder engagement

CONTEXT will implement a stakeholder engagement strategy based on the Lippitt-Knoster model for change management (also see WPD). For this, it is essential to incorporate stakeholder perspectives from the start (co-design) and collaborate in developing the outputs (co-creation). All WPs will directly collaborate with relevant stakeholders to ensure that their perspectives are central to the development process right from the start.

Table 2 summarizes the key elements of stakeholder engagement throughout the project. Central to our stakeholder engagement strategy is the **Stakeholder Forum (SF)**, where our co-funder and all cooperation partners are united. Importantly, relevant external stakeholders (not yet committed to the project) will also be invited to join the SF. The SF is active from the start of the project to ascertain that our activities are aligned with stakeholder's interests, taking into account e.g., ethical, privacy, organizational, monetary, and social aspects. The SF will convene twice per year to provide **input on the design, assumptions, and outputs** of the project and the strategies to implement findings in practice, culminating in an implementation roadmap to guide impact beyond the duration of the project. During each meeting, the SF is asked for input related to testing certain assumptions, specific feasibility issues, and thinking along about progress and co-creation challenges. The SF will provide guidance on facilitating dissemination and utilization of results, and communication of insights obtained to a variety of audiences (see below under Communication). CONTEXT will actively involve specifically the perspectives from police officers and youth, making sure that the diversity of their experiences and views is taken into account. WPA and WPB will coordinate these efforts for police and youth, respectively.

***Table 2**: CONTEXT stakeholder engagement. *Consortium partners in bold; others are external stakeholders*

Stakeholder	Individuals / organizations*	Engagement strategies
Police	Police officers and recruits; **CWC**; Unions (**PZP**, NPB, ANPV)	Co-define goals and concepts (WPC-D; M1-M24) Co-design scenarios used for VR training (WPA, WP2; M1-12) Co-design biofeedback and JITAI interventions (WPA, WP2-3, M12-24) Participate in studies testing neural mechanisms (WP1, M24-84) Participate in studies testing VR biofeedback training and JITAI (WP2-3; M36-84) Co-define intervention goals and outcomes (WPD; M24-96) Co-design roadmap to future implementation (WPD; M72-96) Participate in Stakeholder Forum (M1-96)
Police training and organization	**Police Academy**; **GOMM**; Individual trainers; education specialists	Co-define goals and concepts (WPC-D; M1-M24) Co-design scenarios used for VR training (WPA, WP2; M1-12) Co-design educational modules (WPD; M1-24) Co-define intervention goals and outcomes (WPD; M24-96) Co-design roadmap to future implementation (WPD; M72-96) Participate in Stakeholder Forum (M1-96)
Youth at risk	Individual youth; **YOPE**; **Halt** youth panel; National Youth Council; **SLM**	Co-define goals and concepts (WPC-D; M1-M24) Co-design scenarios used for VR training (WPB, WP2; M1-12) Co-design biofeedback and JIT interventions (WPB, WP2-3, M12-24) Participate in studies testing neural mechanisms (WP1, M24-84) Participate in studies testing VR biofeedback training and JITAI (WP2-3; M36-84)Co-define intervention goals and outcomes (WPD; M24-M96) Co-design roadmap to future implementation (WPD; M72-96) Participate in Stakeholder Forum (M1-96)
Youth (forensic) care	**Halt**; **Levvel**, **Fivoor**; **iHUB**; Youth care professionals; Forensic social workers; Youth workers	Co-define goals and concepts (WPC-D; M1-M24) Co-design scenarios used for VR training (WPA, WP2; M1-12) Co-define intervention goals and outcomes (WPD; M24-M96) Co-design roadmap to future implementation (WPD; M72-96) Participating in Stakeholder Forum (M1-96)

Psychologists / psychiatrists	Nijcare, **ArQ**	Co-design roadmap to future implementation (WPD; M72-96) Participation in Stakeholder Forum (M1-96)
Healthcare insurance	**PZP**; CZ	Co-design roadmap to future implementation (WPD; M72-96) Participation in Stakeholder Forum (M1-96)
Mental health organizations	MIND; **MIND Us**; @Ease; Trimbos Institute	Co-define goals and concepts (WPC-D; M1-M24) Co-design roadmap to future implementation (WPD; M72-96) Participation in Stakeholder Forum (M1-96)
Government	Municipalities (e.g. **Emmen**); Ministries (Health, Education Justice; **MinDef**)	Co-define goals and concepts (WPC-D; M1-M24) Co-design roadmap to future implementation (WPD; M72-96) Participation in Stakeholder Forum (M1-96)
Education	MBO (e.g. **Albeda**); highschools (various); HBO (**HR**)	Co-define goals and concepts (WPC-D; M1-M24) Co-design roadmap to future implementation (WPD; M72-96) Participation in Stakeholder Forum (M1-96)
First responders beyond police	Ambulance personnel; **KMAR**; **MinDef**; **Fyment**;Firefighters	Input on roadmap to future broader implementation for other target groups (WPD, M60-96) Participation in Stakeholder Forum (M1-96)

4.2.2. Communication

Internal communication **-** All scientific and societal partners participate in the General Assembly (see Section 4.3) to jointly discuss the coherence and direction of CONTEXT. Internal communication is facilitated by a project manager, under supervision of the Steering Committee (see Section 4.3). Communication includes: 1) central scheduling and logistics of WP meetings, 2) bi-annual meetings across WPs, 3) training for early- and mid-career researchers, 4) circulars distributed by the Steering Committee, 5) annual CONTEXT conferences, and 6) postings on our website. Frequent internal meetings will be held to discuss progress and facilitate joint, consensus-based decisions regarding the project activities and direction.

External communication **-** Effective communication is essential to increase public awareness about emotion regulation in high-stakes contexts. We will thus ensure widespread communication of the project aims, derived knowledge, tools, and (educational) strategies (Table 3). All consortium members will engage in communication about the project and its results. This will be actively supported by a central **knowledge broker** (0.4 fte) fully committed to raising interest in, understanding of, and support for our goals and results.

Table 3*: Summary CONTEXT communication strategy.*

Communication purpose	Means, type of activities, and timing of activities
Target group: General public, including professionals and youth	
- To raise public awareness of dealing with emotions under stress - To reduce stigma on inadequate emotion regulation	- Public debates, including emphasis on ethical aspects (starting at M6, each year) - Science communication e.g. at InScience festival, Radboud Reflects (M3-96) - Podcasts where consortium members and involved stakeholders discuss emotion regulation with guests (M3-96) - Posts and discussions on social media accounts (LinkedIn, Instagram, X, Tiktok) (M1-96) - Public CONTEXT website and newsletters (M3-96) - Press releases, newspaper-, tv-, and radio appearances (M1-96) - Publication in Dutch journals for broad public (e.g., Quest, KIJK) (M6-96)
Target group: Police trainers	
- To raise awareness of individual differences in emotion regulation under stress - To promote novel ways to train emotion regulation in police	- Knowledge documents for trainers (M1-M24) - Posts and discussions on social media accounts (LinkedIn, X) (M1-M96) - Publications in Dutch and English professional journals (M6-96) - Presentations and informal discussions at professional conferences, e.g., 'Kennis voor de politie van morgen' (annually, throughout project) - Public CONTEXT website and newsletters (M3-96) - Direct interactions through existing networks of CONTEXT applicants (M1-96)
Target group: (Forensic) youth care workers	
- To raise awareness of individual differences in emotion regulation under stress - To promote novel ways to train emotion regulation in youth	- Informative leaflets for youth care workers (M1-M24) - Posts and discussions on social media accounts (LinkedIn, X) (M2-M96) - Publications in professional journals (throughout the project) - Presentations and informal discussions at professional conferences, e.g., EFCAP congress for forensic youth professionals (annually, throughout project) - Presentations followed by informal discussions aimed at (forensic) youth care workers through cooperation partners (annually) - Public CONTEXT website and e-newsletters (M3-96)

	- Direct interactions through existing networks of CONTEXT applicants (M1-96)
Target group: Schools (high schools, MBO, HBO)	
- To raise awareness of prevention of emotion regulation problems - To promote structured attention for emotion regulation in schools	- Publications in Dutch professional journals (e.g., Het Onderwijsblad) (M6-96) - Presentations and informal discussions at professional conferences (annually) - Posts and discussions on social media accounts (LinkedIn, X) (M3-96) - Public CONTEXT website and e-newsletters (M3-96) - Direct interactions through existing networks of CONTEXT applicants (M1-96)
Target group: Professionals in cure and care of emotion regulation-related mental health symptoms	
- To raise awareness of the individual differences in emotion regulation (needs) - To promote effective interventions to improve emotion regulation	- Publications in Dutch and English professional journals (e.g., NTvG, TFPP, Youth in Development) (M6-96) - Presentations and informal discussions at professional conferences (annually) - Posts and discussions on social media accounts (LinkedIn, X) (M3-96) - Public CONTEXT website and e-newsletters (M3-96) - Direct interactions through existing networks of CONTEXT applicants (M1-96)
Target group: Policy makers and health insurers	
- To promote uptake and reimbursement of evidence-based strategies for emotion regulation.	- Presentations and informal discussions at governmental bodies (start M12, each 2 years) - Presentations and informal discussions at health insurance companies about stress prevention programs (annually) - Posts and discussions on social media accounts (LinkedIn, X) (M1-96) - Public CONTEXT website and e-newsletters (M3-96) - Direct interactions through existing networks of CONTEXT applicants (M1-96)
Target group: Scientific community	
- To promote collaborative interdisciplinary research on (individual differences in) emotion regulation	- Scientific publications in open access peer-reviewed journals (M6-96) - Formal presentations and informal discussions at >10 (inter)national scientific conferences (M12-96) - Peer-to-peer interactions through the international scientific networks of CONTEXT applicants (M1-96)

4.2.3. Monitoring & Evaluation

Several monitoring levels together ensure **effective progress monitoring** of CONTEXT (see Section 4.3 for the organizational structure). At the level of PhD or postdoc projects, progress is monitored by their supervisory team. At the level of the Work Packages, progress is on the agenda of every WP Team meeting. WP progress reports are delivered to the Steering Committee (SC) every 3 months. WP Leaders also proactively inform the SC about breakthroughs and potential deviations or risks that may affect the project as a whole. The SC monitors progress of all WPs during each meeting, including based on defined milestones (Table 4). Here, exciting outputs or opportunities as well as deviations from the original plan are discussed, and decisions are made regarding risk mitigation or necessary changes in tasks or budget distribution. Links between subprojects are discussed, with the objective to optimize harmonization of all activities towards the project's overall goal.

Table 4: *CONTEXT milestones*

	Milestone	Means of verification
M7	Experimental model for flexible emotion regulation	Model ready for testing target groups
M12	Validated EMA/EPA tools	EMA/EPA tools validated in pilot studies and ready to start observational studies
M24	Initial theory of optimal emotion regulation	Theory ready for publication in scientific journal
M36	VR-biofeedback and JITAI co-designed with professionals and youth	VR-biofeedback and JITAI ready for interventional study
M36	Feasible integrated JITAI platform ready	Feasibility and reliability validated in pilot studies, full setup ready for interventional study in target groups
M48	Baseline for interventions professionals	Observational study on neural and daily-life mechanisms in professionals completed
M60	Baseline for interventions youth	Observational study on neural and daily-life mechanisms in youth completed
M72	VR-biofeedback and JITAI tested in professionals	Intervention study in professionals completed
M84	VR-biofeedback and JITAI tested in youth	Intervention study in youth completed
M84	Revised theory of optimal emotion regulation	Empirical data integrated in revised theory
M96	Roadmap towards implementation	Final roadmap discussed with stakeholder forum and updated based on that

4.2.4. Capacity strengthening

To optimize the potential of project outputs leading to outcomes, capacity development in several areas will be necessary. Throughout the project, we will regularly discuss needs and potential for capacity strengthening for the consortium itself and for different stakeholders with our **Stakeholder Forum (SF)**. At this stage, we have identified 3 key areas where such needs are foreseen:

Training of consortium members – Due to the combined expertise in the CONTEXT consortium members we will use a train-the-trainer approach within the consortium. We will start with discussing the needs within the consortium and provide training accordingly. For example, training in VR will be provided by members from WP2, training in PAR will be provided by WPA, training in focus groups by WPD.

Training of professionals – To train the professionals we will have regular meetings with both the trainers at the Police Academy and the youth care workers about their needs and how to implement the training in an evidence-based and sustainable way. We will use a train-the-trainer approach within the Policy Academy by providing regular training moments to ensure that they will be able to effectively and independently pursue the CONTEXT-training in the future. We will use the same approach for the (forensic) youth care workers, and specifically tailor this to the different programs within these youth care institutions and based on the stakeholder needs.

Personnel – Within the Police Academy there are trainers available specifically for the goal of implementing the training and educating the recruits and police officers, so no extra personnel is needed for the professionals at risk target group. For the youth care institutions, this might differ per location, so we will have discussions with the specific locations to identify their needs and time schedules.

4.3 Project governance and project management

4.3.1. Project governance

The governance structure of the CONTEXT consortium (Figure 4) is designed to ensure effective high-level decision-making (executive level) and optimal implementation of the project (operational level), while optimally providing strategic oversight (strategic level).

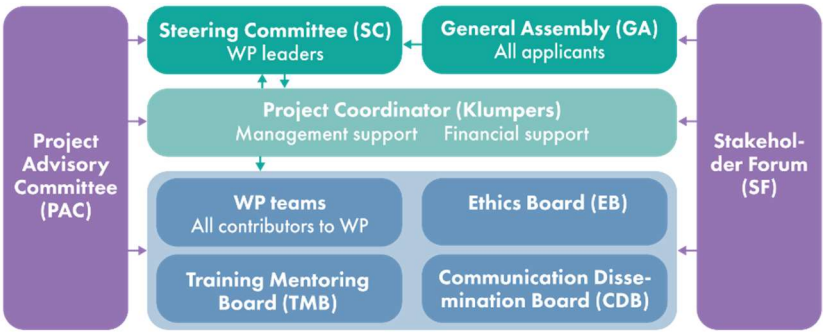

Figure 4: *CONTEXT governance structure*

At the executive level, the **Project Coordinator** acts as intermediary between consortium partners and the funding agency, overseeing proper implementation of the project, communications, and handling all necessary documentation and reporting. The Project Coordinator chairs the General Assembly and Steering Committee, fosters collaboration among participants, leads composition of progress reports, and consults the Advisory Board as needed. The project coordinator is supported by a Project Manager (0.4 fte). The **General Assembly** (GA) consists of one voting representative from each applicant organization, along with all other applicants. The GA is the ultimate decision-making entity. It has the authority to decide on key changes to the project, budget, amendments to the Consortium Agreement, and intellectual property, either at its own initiative or as proposed by the **Steering Committee** (SC). The GA also forms a platform for project coordination and for exchange of scientific results. GA meetings take place annually, but additional meetings can be held upon request of the SC. The GA is chaired by the Project Coordinator. The **Steering Committee (SC)** consists of all WP leaders, and functions as an executive board. It will meet on a monthly basis to discuss details of implementation, including time schedules, budgets, and scientific content, particularly those that transcend individual WPs. The SC monitors progress of the different WPs and the status of milestones, supports the Project Coordinator in interactions with the funding agency, and coordinates communication of the consortium (e.g., press releases). It will furthermore prepare the agenda for GA meetings and, if necessary, propose amendments to the Consortium Agreement and/or budget shifts.

At the operational level, work packages (WPs) are headed by **Work Package Leaders (WPL)** who oversee a major subdivision of the project. WPLs manage day-to-day activities of the applicants and cooperation partners in the WP, actively plan and monitor its progress, and chair related meetings or discussions. They are responsible for timely delivery of milestones and deliverables of their respective WPs, and report to the SC and GA. The **Ethics Board** (EB) consists of representatives of each of the applicant organizations and will focus on ethical issues including (multi-center) medical-ethical protocols, but also cover research integrity, data management, data

sharing, privacy issues, and adherence to FAIR principles. The **Communication and Dissemination Board** (CDB) consists of representatives of each of the applicant organizations. Its task is to develop a communication and dissemination policy, with the aim to ensure that research outputs are carefully prepared and coordinated between partners. The CDB will provide guidance on internal review and approval of research outputs before they are submitted to external platforms and will ensure that fair credit is given to all contributors, including early-career researchers. The **Training and Mentoring Board** (TMB) consists of representatives of all applicant organizations and one early-career researcher employed on the project and is supported by the Project Manager. It will oversee all educational activities of the consortium (see Section 4.4). Also, it will assign a mentor (mid-to-senior career level) to each of the early-career researchers employed on the project.

At the strategic level, the **Project Advisory Committee** (PAC, Table 5) is a consultative body formed to monitor and enhance the scientific quality and societal impact of CONTEXT. PAC members are invited to attend GA meetings to provide feedback on the consortium's progress. The **Stakeholder Forum** (SF) consists of a wide range of representatives of cooperation partners and external stakeholders (see Table 2). The SF is chaired by the leader of WPD (Impact) and has rotating memberships. It will discuss outcomes of the project, identify areas of potential societal impact as well as factors that may hinder impact, and give (un)solicited strategic advice.

Table 5: *Composition of the Project Advisory Committee*

Name	Affiliation	Role	Expertise
Leonard Kok	Police Academy, NL	co-funder (internal)	Training of (future) police officers
Janet ten Hoope	Bureau Halt, NL	cooperation partner (internal)	Preventing and combating juvenile delinquency
Name to be determined	Ministry of Health, NL	societal expert (external)	(Mental) health, policymaking
Name to be determined	Ministry of Justice and Safet, NL	societal expert (external)	Safety, forensic care, policymaking
Prof. dr. Essi Viding	University College London, UK	scientific expert (external)	Developmental psychopathology
Dr. Tim Fawcett	University of Exeter, UK	scientific expert (external)	Optimality modeling, animal behavior
Prof. dr. Talma Hendler	Tel Aviv University, IL	scientific expert (external)	Emotional responses to stress; fMRI
Prof. dr. Judy Illes	University of British Columbia, CA	scientific expert (external)	Neuroethics

4.3.1. Internal collaboration and support

We strive for decisions at all management levels to be made based on consensus. Based on previous and ongoing collaborations among partners and a clear shared vision, we expect the risk of conflicts between applicants to be very low. However, if conflicts do arise between participants, which they cannot resolve together, they shall notify the Steering Committee immediately. A minimum of 2 Steering Committee members, not involved in the conflict, will discuss the issue and strive to come to a consensus-based solution. If timely consensus-based resolution of the conflict is not possible, the PAC will be requested to intervene.

CONTEXT consortium meetings include activities inviting **peer coaching and joint reflection on collaborative procedures**. We will implement a stepped leadership approach, facilitating career development of current team members as well as of personnel to be recruited. In practice, this means that talented researchers will have the opportunity to take the next step in their career under mentorship of a more senior researcher. This includes, where relevant, transfer of leadership of tasks and/or WPs from senior PIs to younger talents over the course of the project. Given their exceptional experience and broad involvement with distinct aspects of the projects, a leadership support team consisting of Prof. Roelofs and Prof. Crone has agreed to function as sparring partners for Project Coordinator Dr. Klumpers regarding strategic leadership of this multifaceted project.

4.4 Involvement and development of young and mid-level researchers within the project

The current CONTEXT consortium comprises researchers at different stages of their careers, including 6 researchers at mid-career level (4 postdocs and 2 assistant professors). CONTEXT foresees to recruit an additional 10 PhD students (early-career) and 10 postdocs (mid-career). To enable these researchers to contribute to the envisioned societal and scientific breakthroughs, and become future leaders in their respective fields, we provide a joint training program and structured mentoring. This is organized by the CONTEXT Training and Mentoring Board (see Section 4.3). All senior applicants have agreed to ensuring time for supervision and mentoring of young and mid-career researchers.

4.4.1. Leadership of mid-career researchers

Leadership of mid-career researchers is enabled via:
- A **stepped leadership approach** where more senior consortium members team up with more junior members; senior members move into an advisory role over the course of the project and empower the mid-career researchers to take the lead in overseeing e.g. specific tasks and WPs.
- Tailored **leadership training** and, where necessary, **training in supervision** of early-career researchers. Peer feedback sessions regarding supervision will be facilitated.
- Contributing to **international exposure and networking** via work visits and collaborations.
- Contributing to **attracting funds for future research** via grant writing training and internal feedback on draft proposals by experienced consortium members.
- Mid-career researchers will be in the lead for their own careers, which is facilitated by **a central mid-career development fund** to organize away days, attend training, and go on academic (international) visits.

4.4.2. Mentoring and supervision

At the start of the project or their recruitment, early- and mid-career researchers will draft a **personal Career Development Plan** (pCDP) in consultation with their supervisor(s), reflecting professional ambitions and the required training and mentoring to meet their needs. The pCDP is discussed and, if necessary, updated, in an annual joint meeting between the researcher and their supervisor(s).

Each **early-career researcher** (PhD student or starting postdoc) is formally supervised by one of the CONTEXT (associate) professors, and has a daily mid-level mentor from the same institution. Scientific interaction will be stimulated by creating mixed PhD supervisory teams from different CONTEXT groups. Where appropriate, we will accommodate cross-group appointments to stimulate cohesion and cooperation. To develop mentoring and leadership skills, early-career researchers are encouraged to mentor Bachelor and/or Master students.

Each **mid-level researcher** is also formally supervised by one of the CONTEXT (associate) professors. In addition, these researchers are encouraged to choose a mentor from the consortium with whom they discuss their career development on an annual basis. All mid-level researchers will gain experience in leadership by co-supervising early-career researchers within the project. Advanced academic leadership courses (including specific female leadership courses) will be offered. These courses are also available to more senior researchers.

A **Junior Thinktank** is established, consisting of two young and two mid-level researchers participating in the project on a 2-year rotation basis. The Thinktank provides feedback on the overall academic climate: onboarding experience, job satisfaction, perceived fit, and work engagement, including regular evaluations among all junior researchers. In addition, it organizes structured peer feedback and (social) events facilitating informal discussions and peer learning across institutes, disciplines, and sectors.

Each early- and mid-career researcher will have access to an **independent Ombudsperson** at their home university of UMC. This Ombudsperson functions as an independent counselor regarding any relevant issues for the individual researcher (e.g. social safety, working conditions, work-life balance).

4.4.3. Training program

The CONTEXT training program consists of a Core Curriculum for all junior researchers and open to mid-level researchers. In addition, there is a wide range of complementary courses and training modules that individuals can choose from, according to their own needs and wishes. The CONTEXT Core Curriculum is open for students from other graduate programs with priority for CONTEXT's own young researchers. The CONTEXT **Core Curriculum** consists of: Multidisciplinary scientific training: Specific courses on e.g. neuroimaging; biofeedback; VR training; formal modeling; participatory action research; and neuro-ethics. Transferable skills training: Specific courses on ethics; co-design and co-creation; open science; communication and dissemination; research integrity & data management. Importantly, young and mid-level researchers within CONTEXT will actively contribute to communication and dissemination events, as well as in the Stakeholder Forum, thus gaining hands-on experience with these important skills.

Next to the Core Curriculum, young and mid-level researchers can choose from a wide range of complementary training modules and courses (**Electives**) available at the consortium partners. Examples of Electives include Donders Summer School on Stress and Cognition; INTRESA monthly seminar series and bi-yearly workshops on how to quantify and model resilience, as well as institutional courses on grant writing, time/project management, academic leadership, etc. In addition, more in-depth scientific content and methodology courses are provided e.g., longitudinal normative modeling (DCCN), Bayesian mixed effects modeling (BSI),

computational modeling (DCC), advanced neuroimaging (DCCN). We will annually update the existing courses in an **Educational Menu** and make that available to all CONTEXT researchers.

4.4.4. Exchange program

Because CONTEXT is an interdisciplinary project, we will set up an exchange program for PhD-students and postdocs. Exposure to other groups within the consortium for at least two months will broaden young researchers' scientific view, skills, technical expertise and network. Exchange will not only be stimulated within academia, but also with non-academic partners such as the Police Academy and Halt.

In addition, early- and mid-career researchers will have the opportunity to pay (joint) visits to European research institutes (including those represented by the scientific members of our Advisory Committee) and relevant stakeholders to obtain more extended international experience.

4.4.5. Optimal preparation for diverse career paths

The personal Career Development Plan (pCDP) of young and mid-career researchers involved in CONTEXT forms a firm basis to steer their own career development and ensure **training that fits their career goals**. This pCDP explicitly allows for gaining competences that are required for a diversity of career paths, including but not limited to science communication (e.g., popular science writing, communicating with stakeholders, media training); teaching (e.g., presenting to professionals; obtaining an official qualification to teach at university); and valorization (e.g., influencing policy, writing business plans, IP identification and protection).

To grow as an independent researcher, building **strong scientific and societal networks** is very important. The CONTEXT consortium provides our talents with easy access to a wide diversity of expertise. Interactions with professionals from across the knowledge chain ensure a broad perspective on scientific and societal issues, thus increasing career perspectives in multiple sectors. Where applicable, early- and mid-career researchers will be introduced to international consortia and collaborators. This will foster international collaboration, e.g., via exchange visits or grants such as Marie S. Curie Fellowships.

5. Research plan

5.1 Research plan and work packages

5.1.1. Aim and objectives

Our central aim is **to enhance societal safety and health by developing a novel, individualized and adaptive emotion regulation training for professionals and youth at risk**. To achieve this ambitious goal, we organize the work according to our three sub-aims, each corresponding to a knowledge gap (KG) and to specific WPs. For all three sub-aims we will use PAR and co-design and we will take along stakeholder perspectives in each step[70-72] to optimize efficacy and sustainability and to determine ethical and legal conditions for societal impact (WPD).

1) To optimize neurocognitive models and interventions, we will first apply our expertise in **theoretical modeling**[70-72] **and modeling of real-life contextual and emotional dynamics** obtained through uniquely integrated ecological momentary assessments of contextual demands, subjective experiences, physiological states, and corresponding actions)[53, 73, 74]. The resulting non-normative understanding of adaptive emotion regulation provides the essential and so-far lacking information on the **context dependency of low- and high-arousal autonomic states and corresponding self-regulation needs, both empirically as well as theoretically** (KG1 - WP3 & WPC-D).

2) Leveraging our expertise in psychophysiology and neuroscience, we will investigate **CNS-ANS interactions** (Figure 1) **in a unique fashion,** by assessing the balance in para- and sympathetic branches of the autonomic nervous system through measures of heart rate variability (HRV) and frequency (HR), and by testing the **impact of autonomic balance on the neural functions that underlie flexible emotional control**[7, 9, 75]. This will lay the neurobiological foundation necessary to develop an optimally personalized self-regulation biofeedback intervention (KG2 - WP1).

3) We will develop an innovative **neurocognitively grounded VR-based biofeedback training** that trains autonomic balance[44, 45, 52]; in ecologically valid (high-arousal, active) contexts to enable skill transfer; and in real time using a dual closed-loop training system (see Figure 6) to optimize biofeedback learning and knowledge anchoring using Just-in-Time Adaptive Interventions (JITAIs) [53, 73, 74] (WP2 & 3). Critically, we will deploy this solution in at-risk youth and first-response professionals (police) (WPA & B) (KG3).

5.1.2. Work plan

The work is defined in five uniquely organized work packages (WPs), that collaborate to **prepare and to conduct two large N observational studies and two large N interventional studies**, in police officers and youth at risk (N=200 each). **Figure 5** illustrates our crossover organization, in which WP 1-3 develop the methodology in a series of smaller N studies, while WP A-D test the innovations in police and youth based on continuous theoretical, ethical and impact considerations.

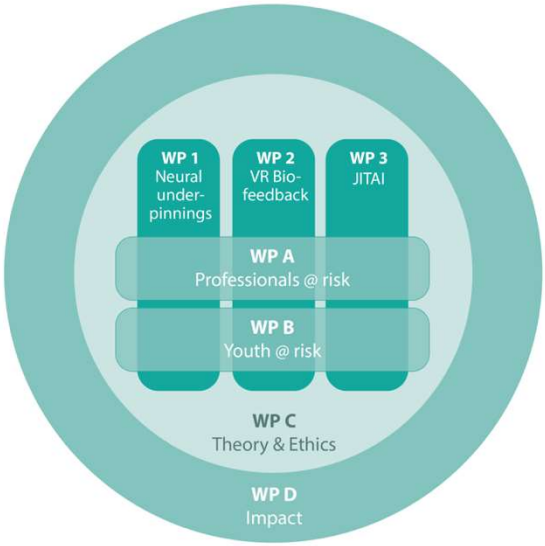

Figure 5: *WPs and their relation. WP 1-3 will each tackle specific questions and methodology development regarding neuro-science (WP1), VR biofeedback (WP2) and a just-in-time-adaptive intervention for feedback in real-life situations (WP3). These WPs intersect with mutually informative WPs for our target groups in which the assessments and interventions are optimized towards and tested in police (WPA) and youth (WPB). Integration of theoretical, ethical and stakeholder perspectives is guaranteed by WPC (theory development and ethics) and D (long-term impact).*

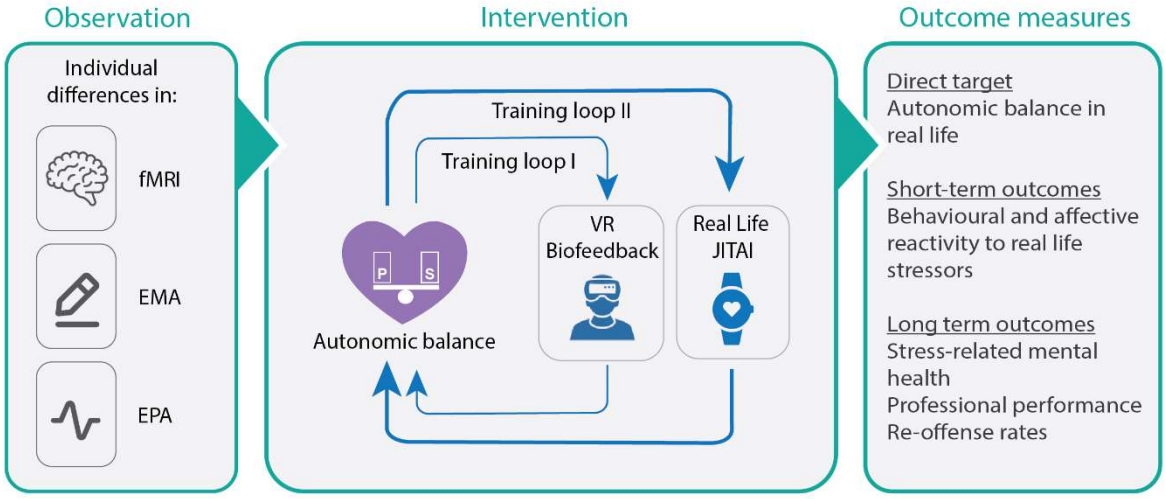

Figure 6. *To establish optimal motivation in learning as well as transfer to real life we will use a dual closed-loop training. The training is grounded in the context-dependent neurocognitive and psychophysiological observations obtained in the observational phase of CONTEXT. The dual closed-loop training involves initial training of individuals' autonomic balance in challenging and engaging gamified virtual reality scenarios followed by subsequent integration of individualized feedback in real-life situations through smartwatch and wearable biosensor-based assessments. In this way, participants receive individualized feedback to improve their autonomic balance in the moments when needed most using a just-in-time approach. The expected impact is improved emotion regulation reflected in improvements in autonomic balance in real-life situations that lead to better mental health (stress symptoms), improved real-life professional performance and reduced aggression.*

WP 1: Impact of autonomic (dis)balance on neural underpinnings of flexible emotion regulation (M1-M84)
WP leader: Prof. dr. Erno Hermans (Radboudumc) **WP personnel:** PhD1, PhD2 **Participating applicants:** Prof. dr. Karin Roelofs (RU), Dr. Floris Klumpers (RU), Dr. Florian Krause (Radboudumc), Prof. dr. Eveline Crone (EUR), Prof. dr. Lucres Nauta-Jansen (AUMC)
Objectives 1. To investigate the impact of acute stress-induced perturbations in autonomic balance (between sympathetic and parasympathetic activation) on emotion regulation systems at different hierarchical levels of prefrontal emotional control circuits (flexible action monitoring/control as well as flexible cognitive regulation of emotion) in volunteers from the general population (18-24 years).

2. To determine the effects of heart-rate variability biofeedback training on neural and peripheral markers and autonomic balance (through correlates of sympathetic and parasympathetic activation), as well as on emotion regulation systems at different hierarchical levels of prefrontal control emotional circuits in volunteers from the general population (18-24 years).
3. To, in target groups (police and youth at risk), determine effects of acute stress-induced perturbations in autonomic balance on emotion regulation systems at different hierarchical levels of prefrontal control circuits and associate these markers with (1) affective reactivity to stressful encounters in real life; and (2) efficacy of the heart-rate variability biofeedback-based intervention.

Approach and link to other WPs

This WP will test our neural framework for flexible neural control of emotion under high-stress conflict conditions (Figure 1) and thereby lay the empirical foundation for the biofeedback-based intervention (WP2) that is applied in target groups (WPA and WPB). We will test the hypothesis that acute stress leads to alterations in both sympathetic and parasympathetic autonomic nervous system activity, and that coactivation of these two systems (i.e., maintaining autonomic balance) creates optimal conditions for flexible prefrontal regulation in high-stress conflict situations. We will adapt and integrate experimental paradigms for monitoring / flexible switching of emotional actions[42, 64] with protocols for controlled induction of stress[7, 65], which will be adapted to experimentally mimic high-stress conflict situations. Co-design with target groups will be implemented to improve ecological validity and feasibility of experimental models. Next, in close collaboration with WP2, we will examine how application of trained self-regulation strategies of physiological states under stress affects neural circuits underlying flexible emotion regulation. Finally, in collaboration with WPA, WPB, and WP3, we will investigate how individual differences in neural circuits underlying flexible emotion regulation within our target groups are linked to affective reactivity during stressful encounters in real life and predict the response to our biofeedback-based intervention.

Methodology

Task paradigm: Using co-design with target group representatives (in collaboration with WPA, WPB, and WPD), we will develop a paradigm for controlled induction of stress and frustration that can serve (within ethical limits) as an ecologically valid model for real-life high-stress conflict situations. For this procedure, we will build on the work of applicants in using psychological / physiological stressors (socially evaluated cold-pressor test) in combination with negative social evaluation of performance in a frustrating task[76-78]. In between blocks of this task, participants perform two ER-flexibility tasks, one in which they are required to select emotional control strategies and switch between freeze and fight/flight actions while monitoring the effectiveness of chosen and alternative strategies[64]. Monitoring of current strategies and flexibly switching between emotional actions has been shown to engage medial and lateral frontopolar regions, respectively (Box 1). To assess dorsolateral prefrontal engagement in cognitive regulation of emotion, we will develop a task in which participants have to flexibly alternate between cognitively regulating affective responses to emotional stimuli through reappraisal or through distraction[5, 42].

Functional MRI and physiological measures: All participants will undergo whole-brain high-resolution multi-band EPI BOLD functional MRI at 3 Tesla with 1mm isotropic resolution to measure task-induced activation. Heart-rate frequency and variability will be monitored using a photoplethysmograph to assess sympathetic and parasympathetic autonomic nervous system activation, respectively. Pupil dilation and skin conductance will be recorded as additional sympathetic measures. Heart rate and respiration recordings will furthermore be used for modeling physiological noise (RETROICOR). To monitor noradrenergic and cholinergic activation in association with sympathetic and parasympathetic activation we will (1) record BOLD signal from projection sites (locus coeruleus and pedunculopontine tegmental nucleus, respectively), localized using a combination of a high-resolution TSE sequence (sensitive to neuromelanin; by-product of monoamine synthesis) and a probabilistic atlas; and (2) assess strength of brain-wide projections of norepinephrine and acetylcholine using receptor-enriched analysis[79] using publicly available noradrenergic and cholinergic receptor expression maps from post-mortem tissue[80, 81] and from PET scans[82].

T1.1: Development of experimental model for flexible emotion regulation under high-stress conflict conditions (M1-M7) **Personnel:** PhD1 **Partners involved: Radboudumc**, RU, EUR, AUMC

Based on earlier work[42, 64, 77] of partners on experimental induction of stress and emotion regulation, we will develop the novel integrated experimental model of high-stress conflict situations described above and test this paradigm in small-scale pilot studies. Psychophysiological measures (subjective self-report, heart-rate

frequency, heart-rate variability, pupil dilation) will be used to verify efficacy of stress induction in affecting sympathetic and parasympathetic activity, as well as success of emotion regulation strategies.

T1.2: Identifying optimal physiological states for flexible emotion regulation under high-stress conflict conditions (M7-M19) **Personnel:** PhD1 **Partners involved: Radboudumc**, RU, EUR, AUMC

To investigate how individual differences in autonomic balance relate to neural signatures of emotion regulation, we will deploy the paradigm developed in T1.1 in a group of 100 participants recruited from the general population (sample size based on power calculation below) in the same age range as the target populations in WPA and WPB (i.e., age 18-23). fMRI measures detailed above allow us to examine ventro-medial, frontopolar, and dorsolateral prefrontal engagement during different forms of emotion regulation.

T1.3: Experimental test of biofeedback training and immediate effects of self-regulation (M19-M30) **Personnel:** PhD1 **Partners involved: Radboudumc**, RU, EUR, AUMC

To experimentally evaluate the effects of the biofeedback training developed in WP2, we will train 30 healthy volunteers (based on power calculation below) to acquire heart-rate variability self-regulation skills. We will then examine the effect of applying this skill using the neuroimaging methods for assessing noradrenergic and cholinergic activation described above, testing the hypothesis that heart-rate variability self-regulation selectively activates cholinergic circuits. We will furthermore test the immediate effect of this self-regulation on flexible emotion regulation during acute stress using the paradigm developed in T1.1.

T1.4: Neural correlates of flexible emotion regulation in target groups in relation to real-life affective reactivity (M25-M49) **Personnel:** PhD1, PhD2 **Partners involved: Radboudumc**, RU, EUR, AUMC

In close collaboration with WPA, WPB, and WP3 we will deploy the paradigms developed in this WP and a battery of established functional MRI tasks (whole-brain functional connectome using resting-state functional connectivity; emotional face-matching task to probe amygdala function, monetary incentive delay task to probe mesolimbic reward system activation; for which large cohort reference data are available[78, 83]) and structural (T1-weighted; DTI) brain imaging modalities in two target groups (N=200 each). Because the same groups are also tested using EMA and EPA in WP3, this will allow us to test whether interindividual variability in neural circuits of flexible emotion regulation is associated with affective reactivity to stressors in real life.

T1.5: Neural correlates of flexible emotion regulation in target groups as predictors of intervention success (M49-M84) **Personnel:** PhD2 **Partners involved: Radboudumc**, RU, EUR, AUMC

In close collaboration with WPA, WPB, WP2 and WP3, we will assess to what extent improvement in flexible emotion regulation in target groups following biofeedback training can be predicted from neural and physiological measures of flexible emotion regulation at baseline (using data acquired in T1.4) acquired before participants are included in the intervention study.

Power calculation

The sample sizes were chosen to maximize the sensitivity of identifying reliable neural correlates of emotion regulation under acute stress. While previous studies in a general population and in the absence of stress have identified many of these correlates using smaller sample sizes[33], there is risk for inflated effect size estimates in these studies due to publication bias. A sample size of N=100 in T1.2 gives us the necessary power (80%) to detect even small neural effects (d = 0.3; with up to 29% dropout). The sample size in T1.3 was chosen to (1) ensure successful heart-rate variability self-regulation via biofeedback training, and (2) ensure that we can capture effects of this on neural measures. While previous studies show robust biofeedback self-regulation effects in VR already with sample sizes as small as n = 9 (indicating very large effects[44]), literature on manipulations of cholinergic/noradrenergic activation (via means other than biofeedback) indicate medium sized effects[7]. We expect a similar (or larger) effect size for biofeedback training. A sample size of n = 30 hence gives us the necessary power (80%) to detect the expected medium sized effects (d > 0.5; with up to 10% dropout). For detecting associations between individual differences in our target groups in relation to real-life affective reactivity (T1.4), N=200 yields sufficient power (80%) for detecting small effect sizes ($|\rho|$ = 0.22; with 20% dropout). For predicting intervention success (T1.5), the N=150 sample for each target group who receive the intervention allows to detect (80% power) even small effect sizes ($|\rho|$ = 0.24; with up to 30% dropout). Power calculations for intervention success are described in WPA and WPB.

Productive interactions (co-design and co-creation)

Co-design and co-creation in collaboration with representatives of target groups (police and youth) will be applied throughout tasks T1.1-T1.4, under supervision of WPA, B and D to (1) optimize ecological validity of our experimental model of emotion regulation in high-stress conflict conditions; (2) ensure feasibility of

laboratory-based tasks in target groups.

Contribution to impact pathway

WP1 will provide novel insights regarding the neural underpinnings of (individual differences in) emotion regulation under stress, contributing to **outcome 1**. It also provides the empirical foundation for the VR/biofeedback intervention, thus ultimately contributing to outcomes **3-7**.

Requested WP budget

Description cost/in-kind contribution	*Amount (€)*
Salary costs PhD students (each 4 years, 1 fte)	622.900,-
Benchfee, travel and publication costs (2* 12k€)	24.000,-
Participant reimbursement (410 hrs * €15)	6.150,-
MRI scan costs (925 hrs * €250)	231.250,-
Data storage costs (€0.30 per GB)	6.256,-
Saliva samples / Cortisol+AA analysis (2650 samples * €9)	23.850,-
Total	892.806,-

Motivation: The first PhD student will have a primarily fundamental focus and develop the stress/conflict paradigms (T1.1/2) and experimentally test the effects of biofeedback training (collaboration with WP2) (T1.3). The second PhD student will start later and collaborate with WPA/B to deploy the paradigm in target groups at two test sites, and will focus on linking neural and physiological parameters to real-life reactivity (T1.4) and intervention outcome (T1.5). MRI scan costs, MRI data storage costs, and saliva samples/analyses (5 samples per subject, salivette, cortisol, and alpha amylase analysis) are included in the WP1 budget. Participant reimbursement for police and youth at risk is budgeted under WPA and WPB, respectively.

WP 2: VR / biofeedback (M1-M96)

WP leader: Dr. Floris Klumpers (Radboud University)
WP personnel: PhD3, PhD4 (shared with WPA & B to support trial), game designer, unity programmer
Participating applicants: Prof. Karin Roelofs (RU), Prof. Erno Hermans, Dr. Carmen Sergiou (AUMC), Dr. Annelinde Vandenbroucke (AUMC)

Objectives

1. To develop engaging and target group appropriate immersive VR environments
2. To develop individualized HRV biofeedback algorithms
3. To optimize biofeedback learning through computational modeling

Approach and link to other WPs

This work package will co-create appropriate emotionally engaging immersive environments with integrated individualized biofeedback to allow for a motivating biofeedback emotion regulation training attuned to the individual. For the biofeedback targets, individualization will occur based on the insights from WP1, 3 and 4. The initial training will be supplemented with personalized reminders developed in WP3. The final intervention will be rigorously tested in WPA and B and co-creation and optimal integration into existing curricula and care will be made possible in collaboration with WPD.

Methodology

This work package will work together with a serious game designer, end users and educational specialists to develop gamified biofeedback training environments through our previously used rapid iterative testing co-creative design procedure[44, 45]. In addition we will use reinforcement learning models to establish and optimize individual learning parameters.

Target groups: The professional at risk group (WPA) consists of two groups of first responders: 1) Recruits from the Police Academy (level MBO, ages 18-25) and 2) Police officers at risk for developing stress-related complaints. The youth at risk group (WPB) is focused on the age group that is most in contact with the police: Youth aged 16-24 years (adolescence and transition phase towards young adulthood).

T2.1: Game design (M1-M36 + M84-96) Personnel: PhD3, PhD4, game designer, unity programmer **Partners involved: RU**, AUMC, EUR, UMCU, UvH

In the first phase we will explore what police and youth-relevant virtual contexts will be. We will build on our experiences with our previously co-designed VR game that was found to be highly engaging and effective[44, 52]. For youth, this phase will start from focus groups discussing what are emotionally engaging yet ethically responsible contexts that could be used (with WPD, A & B). This input will be used by the game designer to develop initial game narratives which will be presented back to stakeholders through storyboarding. Once a

concept is agreed upon, the game design will be worked out in a basic virtual environment (sandbox) for rapid iterative testing. For police, we will gather user experience data from police recruits to verify and update our previous development based on input from police trainers. The contexts will be developed to allow variation in how emotionally provocative they are in the form of game levels so that they can be adapted to allow emotion regulation practice in a context most suitable to the individual. After the games have been used in rigorous testing we will update the design.

T2.2: Biofeedback design (M12-M36) **Personnel:** PhD3 **Partners involved: RU**, EUR, AUMC, UvH, UMCU

In this task we develop the heart rate variability biofeedback algorithms at the core of the intervention. Early explorations with partners and stakeholders indicate there will be at least two distinct biofeedback targets: HRV upregulation and HRV downregulation depending on situational and individual demands. These targets will be further refined in focus groups with stakeholders (with WPA/B/5), mechanistic insights from WP1 and based on EMA/EPA observations from WP3 on physiological signatures for adaptive regulation. Subsequently we translate these targets into observable and motivating biofeedback in the game (e.g. by changing the visibility in the game; the exact biofeedback mechanic will need to be attuned with the game environment developed in T2.1). Finally, we develop the algorithms that describe how an individual's HRV value is translated to biofeedback in a manner that feels reliable and responsive and that is adapted based on the individual's performance. This is inspired by our earlier biofeedback interventions but will require attuning to the individual target groups.

T2.3: Small-N assessment (M24-M36) **Personnel:** PhD3 **Partners involved: RU**, EUR

We will use a small N experimental design as a first evaluation of the intervention (game + biofeedback) effects[44]. Testing will take place in police recruits (N=10) and youth at risk (N=10) carefully selected to represent the population in which we aim to implement the intervention. While the small N potentially limits the generalizability of results, this intermediate step is crucial to finetune development before large scale assessment in the RCT (see T2.4). Outcome parameters will be biofeedback score (i.e. development of the individual's HRV towards their personalized target), user experience (arousal, engagement/motivation) and physiological awareness (awareness of the biological markers of arousal: heart rate and breathing). All these processes can be measured effectively at an individual level in a small-N design[44]. Based on the results we will update the VR game and biofeedback to further improve the game's effectiveness.

T2.4: Randomized Controlled Trial (M38-M84) **Personnel:** PhD3 & PhD4 **Partners involved:** RU, EUR

In collaboration with WPA and B the integrated intervention will be assessed in sufficiently powered samples using a randomized controlled trial in both target groups. The interventions are described in detail in WPA and B. The EMI reminders will be based on the individual's biofeedback training to give empirically validated and individually attuned feedback.

T2.5: Biofeedback computational modeling (M60-M84) **Personnel:** PhD4 **Partners involved:** RU

While biofeedback is widely acknowledged to be a form of reinforcement learning, the development of biofeedback is not profiting from recent advances in understanding of reinforcement learning from computational modeling approaches. These approaches allow to better grasp how observable outcomes (in this case development of biofeedback score) are mathematically linked to a combination of observable (e.g game dynamics, biofeedback representation)) and latent factors (e.g. the individual responsiveness to negative and positive feedback and how fast the individual update's their behavior based on this)[84]. We will adapt recently developed computational models of behavior based on reinforcement learning to assess the critical determinants of biofeedback efficacy in the RCT data and based on these findings can update the game environment and biofeedback algorithm.

Productive interactions (co-design and co-creation)

This WP depends critically on co-design of believable and engaging virtual environments with both youth and police. For this, we collaborate with WPA,B and D. Moreover, future integration of the training in the relevant educational and (forensic) care contexts is enabled in collaboration with WPD via co-creation sessions with the Police Academy, the National Police, PZP, and the CWC (for police) and Halt, Levvel, Fivoor, and iHUB (for youth at risk), respectively.

Contribution to impact pathway

WP2 will deliver engaging and arousing VR biofeedback interventions (2 different versions for police and youth) to train flexible emotion regulation. Co-design and co-creation from the start will directly contribute to achieving **outcomes 3-6** (related to implementation of the training for police) **and 7** (related to

implementation of the training for youth at risk. Finally, insights in how to tailor VR biofeedback training to different target groups will contribute to **outcome 2**.

Requested WP budget

Description cost/in-kind contribution	*Amount (€)*
Salary costs 2 PhD students (each 4 years, 1 fte)	609.278,-
Benchfee, travel and publication costs (2* 12k€)	24.000,-
Salary costs 1 game designer (2,5 years, 0.4 fte)	104.494,-
Salary costs 1 unity programmer (2,5 years, 0.4 fte)	104.494,-
10 Quest 3 headsets	5.000,-
20 polar H10 HR sensors	1.000,-
Participant reimbursement (T2.3)	1,000,-
Total	849.266,-

Motivation: One PhD student will be involved in the early development and design and testing. The second PhD student will work mainly on the RCT in collaboration with PhDs from WPs A and B. The game designer will together with the programmer develop the virtual reality games, and, based on user experience, study outcomes and demands by stakeholders adapt them in the final stage of the project. We will acquire 10 quest3 VR headsets for each target group to be able to test simultaneously in different sites and allow for parallel testing with up to 4 individuals to boost the speed of data collection. 20 HR sensors will be acquired with appropriate variation in belt sizes to accommodate the different target groups. Note that participant reimbursement for police and youth at risk is budgeted under WPA and WPB, respectively.

WP 3: Just In Time Adaptive Interventions (JITAIs) (M1-M96)

WP leader: Dr. Marta Marciniak (Erasmus University Rotterdam)
WP personnel: PhD5, Postdoc1, Postdoc2 (shared with and budgeted in WPD)
Participating applicants: Prof. Erno Hermans (Radboudumc), Dr. Florian Krause (Radboudumc), Prof. Eveline Crone (EUR), Dr. Ilse van de Groep (EUR), Dr. Floris Klumpers (RU), Prof. Lucres Nauta-Jansen (AUMC)

Objectives

1. To develop and test a stress detection algorithm using EMA and EPA.
2. To develop and test tailored EMI separately for both target groups (WPA and WPB).
3. To integrate EMA, EPA, and EMI into a unified JITAI platform and perform feasibility tests.
4. To evaluate the platform's potential for a broad implementation in real-life settings.

Approach and link to other WPs

WP3 will develop and test an algorithm to detect stress levels in target groups, alongside implementing Just-In-Time Adaptive Interventions (JITAI) as part of flexible emotion regulation training in real-life settings and will be closely linked to other work packages. Ecological Momentary Assessment (EMA) and Ecological Physiological Assessment (EPA) will be refined with WPC to capture stress-inducing experiences and physiological markers of stress, providing baseline data for the algorithm. Additionally, Ecological Momentary Interventions (EMIs) will be developed to reinforce biofeedback training, with content informed by WP1 and WP2. The integrated JITAI platform, will be further refined and tested in large-scale interventional studies by WPA and WPB. WP3 also will collaborate with WPD to optimize the platform for broad implementation, ensuring maximal impact, sustainability, and dissemination to relevant stakeholders.

Methodology

The methodology of WP3 is grounded in ecological momentary approaches, incorporating three key components: EMA for capturing self-reported stress levels in real-life contexts, EPA for measuring physiological arousal (i.e., spontaneous skin conductance response and heart rate), and EMIs, interventions delivered in real-life contexts. EMIs will complement the biofeedback training developed in WP2 by extending the application of learned strategies beyond the laboratory and into real-world settings. Further, they will be co-created with the target using qualitative methods like focus groups to ensure their contextual relevance. Each of these components, EMA, EPA, and EMI will be implemented through an RU-based platform designed specifically for ecological momentary-based studies, which has been used and validated in our prior research, i.e., EU Horizon2020 project DynaMORE[73, 74, 78]. The components will undergo rigorous evaluation through a series of small-scale pilot trials, as described in each task.

These components—EMA, EPA, and EMI—will be integrated into a unified platform, where advanced statistical modeling will translate real-time data into an algorithm for detecting stress and delivering Just-in-Time Adaptive Interventions (JITAI). Specifically, individualized means and standard deviations will be used to

Z-score real-time EMA/EPA data. To correct for motion, a linear regression will be fitted between accelerometer data and Z-transformed EPA values. Finally, combined EMA and motion-corrected EPA Z-scores will be averaged to form a stress detection score and trigger a contextually dependent JITAI chosen from a pre-specified set of EMIs (Figure 7). The system will be rigorously validated and refined through further small-scale pilot feasibility tests, ensuring the precise, personalized delivery of interventions during critical stress moments. By engaging participants in this second loop of training, the JITAIs enhance the transfer of skills from controlled environments to everyday contexts.

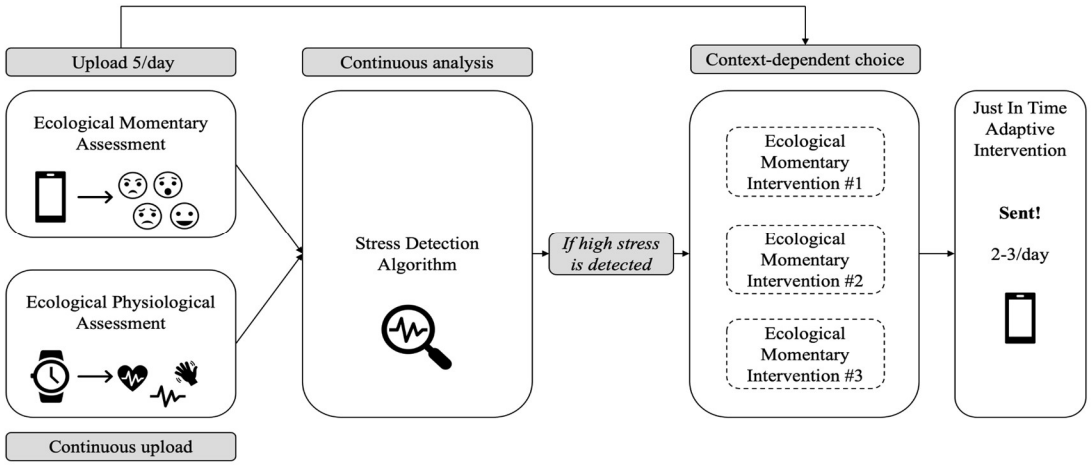

Figure 7: *The architecture of the integrated JITAI platform*

T3.1: Defining, developing, and validating EMA and EPA measures (M1-M12) Personnel: PhD5, PD1 **Partners involved: EUR**, Radboudumc, RU

We will define and develop the EMA questionnaire, delivered via mobile app, and select a set of biosensor variables gathered via smartwatch-based EPA. The development process will involve collaboration with WP1, WP2, WPA, WPB, and WPC to ensure alignment with biofeedback training and population needs. We will focus on implementing questions related to stressor exposure and reactivity, which will capture real-life variability. The devices will be connected to the RU infrastructure, ensuring that data from both EMA and EPA are collected and stored online in compliance with national and EU GDPR legislation. Pilot testing with n=30 participants per target group (WPA/WPB), will ensure data quality as well as minimized participant burden in the main observational study (n=200). Participants will be continuously monitored using EMA/EPA tools for 4 weeks. During each week, we will acquire up to 35 EMA observations and 24/7 EPA using a smartwatch. If proved acceptable by the target populations, they will be integrated into the main observational study conducted by WPA and WPB following the same delivery design.

T3.2 Developing and validating an EMA/EPA-based high-stress detection algorithm (M12-24) Personnel: PD1, PhD5 **Partners involved: EUR**, Radboudumc, RU

The ultimate goal of this task is to develop a precise and reliable algorithm for detecting high stress, with a focus on adaptiveness, i.e., dynamically adjusting the stress threshold needed to trigger a JITAI to deliver it at optimal time points, as described above. Before implementing it in the interventional studies across WPA and WPB, we will test the algorithm in pilot feasibility tests with n=30 participants per target group. Participants will follow the same study design as in T3.1 with the aim of detecting at least two, and a maximum of three high-stress instances per day.

T3.3 Defining, developing, and validating EMIs for both populations (M6-M36) Personnel: PhD5 **Partners involved:** EUR, Radboudumc, RU, UvA

We will develop innovative EMIs to enhance the efficacy of biofeedback. WP2 will identify a range of factors for potential inclusion in these EMIs. WP3 will then select the three most promising targets for translation into engaging mobile app environments and will develop effective, brief interventions. To ensure their relevance, two distinct sets of EMIs will be created: one tailored for professionals (WPA) and another for youth (WPB). To ensure not only their feasibility but also efficacy in decreasing levels of stress before the main interventional study, these EMIs will be first tested as standalone apps with n=50 participants in a longitudinal four-week design. The power calculation (80% power, 0.05 significance level, 0.6 Cohen's d)[85, 86] revealed required 47 participants per group and an additional 3 to account for the attrition rate).

T3.4 Integrating the JITAI platform and feasibility testing (M24-M36) **Personnel:** PD1, PhD5 **Partners involved: EUR**, Radboudumc

We will integrate EMA, EPA, EMI, and a high-stress detection algorithm into a JITAI platform. It will continuously analyze incoming EMA and EPA data to detect stress and trigger EMIs at optimal moments, thus delivering them as JITAIs. Following this integration, we will conduct a series of iterative pilot feasibility tests with n=30 participants in each trial to evaluate the platform's reliability, and efficacy in delivering JITAIs. Participants will be monitored for 4 (burst) weeks using EMA/EPA tools, including up to 35 EMAs per week and continuous EPA data from smartwatches, with the aim to receive at least 2 and a maximum 3 different EMIs per day on the high-stress moment decided by the algorithm. We opt for a burst delivery design, i.e., delivery of interventions only in pre-defined time windows (i.e., one week per month) to lower participant burden and assess long-term effects of emotion regulation flexibility training. Previous work showed that delivering EMIs in a burst design did not have an impact on effectiveness and adherence to interventions, and it decreased perceived difficulty of EMIs for study participants[85].

T3.5 Evaluating the platform for broad and sustainable dissemination (M36-M96) **Personnel:** PhD5, PD1, PD2 **Partners involved: EUR**, AUMC

Leveraging the expertise of WP3 and WPD, we will explore the potential for the JITAI platform's broad dissemination. This will involve potential of scalability and adaptability for diverse user groups, including police and youth, following the outcomes of the main studies by WPA and WPB. We will also consider the feasibility of the platform as a standalone, cost-effective, and maintainable training tool for long-term engagement. The findings will be compiled into a report and presented to key stakeholders to gather feedback on potential valorization opportunities.

Productive interactions (co-design and co-creation)

We will actively involve youth and professionals in the co-creation of the EMA and EMI. Engaging these user groups throughout the process ensures that the tools are tailored to their specific needs, and preferences, ultimately enhancing the impact and real-world applicability of the JITAI platform.

Contribution to impact pathway

WP3 will provide novel insights on real-life stress dynamics and physiological aspects related to emotion regulation, as well as advanced algorithms to determine optimal timing JITAIs. This will directly contribute to **outcomes 1 and 2**. Our co-created engaging and context-based EMIs (in 2 different versions for police and youth), will provide personalized, scalable support for stress management and emotion regulation. This will contribute to **outcomes 3-6** (police) and **7** (youth).

Requested WP budget

Description cost/in-kind contribution	*Amount (€)*
Salary costs PhD student (4 years, 1 fte)	304.639,-
Salary costs Postdoc (3 years, 1 fte)	295.562,-
Benchfee, travel and publication costs (1* 12.000 and 1* 12.500)	24.500,-
Smartwatches and smartphones for EMA/I and EPA (200€ + 300€ * 100 participants)	50.000,-
JITAI infrastructure setup and maintenance, incl. data storage and connectivity coss	113.000,-
Participant reimbursement (280 participants * 10€ per week * 4 weeks)	11.200,-
Total	798.901,-

Motivation: The PhD student will contribute to T3.1–3.5, focusing on data collection during feasibility trials and specifically, the development of EMA (T3.1) and EMI (T3.3). Additionally, the student will have an opportunity to explore dissemination options for the platform (T3.5). The Postdoc with expertise in implementation processes, will provide critical support during the development of the stress-detection algorithm (T3.2 and T3.4), including the extraction of EPA data (T3.1). PI Marciniak will, in collaboration with the Postdoc budgeted in WPD, further assess the platform for a broad dissemination (T3.5). To avoid excluding participants who may not own a smartwatch or possess older smartphones incompatible with the platform, we will provide each participant with a device set (estimated at €500 per set). This approach will help mitigate potential disruptions from software updates, ensuring consistent performance of the platform throughout the study. Infrastructure costs, including setup and secure data storage (35,000€), fast internet connectivity for data transmission (48,000€), and maintenance during the study period (30,000€), are budgeted. Participant reimbursement for police and youth at risk is budgeted under WPA and WPB, respectively.

WP A: Professionals at risk (M1-M96)

WP leader: Prof. Karin Roelofs (Radboud University)

WP personnel: PhD4 (with WP2), PhD6, 7, PhD8 (with WPB), Postdoc2 (with WPD), Postdoc3, Postdoc4, RA1
Participating applicants: Prof. Annika Smit (UvH), Dr. Floris Klumpers (RU), Dr. Willem Frankenhuis (UvA), Dr. Karin Jongsma (UMCU), Prof. Erno Hermans (Radboudumc), Prof. Eveline Crone (EUR), Dr. Marta Marciniak (EUR)

Objectives

1. To refine and contextualize the research questions on emotion regulation in high stress environments, based on PAR with police officers in training at risk (with WPC-D).
2. To test mechanisms of emotion regulation using contextualized approach-avoidance paradigms (with WP1 on brain mechanisms and WP2 on daily variability), in the police professionals at risk.
3. To co-design dual loop interventions with police recruits and officers and trainers, including closed-loop VR-based biofeedback (with WP2) and (just-in-time-interventions (with WP3).
4. To test the effects of interventions on flexible emotion regulation skills in acute situations and in the long run on changes in neural mechanisms (with WP1) and in daily life (with WP3).
5. To assess transfer of bio-regulatory skills in real life *interactions* (with WPB and WPD).

Approach and link to other WPs

This WP will focus on contextualized, co-designed assessment of emotion regulation mechanisms and co-development and rigorous testing of the effectiveness of the dual loop intervention in young police officers at risk. Given the (partial) overlap in expected emotion regulation mechanisms between our target groups, as well as the interpersonal nature of high-stake stress situations involving both police and youth, this WP will be closely aligned with WPB (youth at risk) and will follow similar procedures and objectives. This WP is intertwined with WP1, WP2 (T2.1-2) and WP3 (T3.1-3) for methodology development, psychophysiological, behavioral and neural assessment, and testing of the intervention components. First, together with WP1, WPA will (1) co-develop the fMRI paradigms related to stress-induction and emotion regulation flexibility (see corresponding tasks T1.1-2), (2) assess the neural correlates of flexible emotion regulation in the police target population (T1.4), and (3) assess whether these neural correlates predict intervention success in police. Second, together with WP2, we will (1) co-create police-relevant virtual contexts (T2.1) and the biofeedback design (T2.2) for the first loop of the intervention, and (2) subsequently test the effectiveness of the biofeedback component of the intervention in the police target population (T2.3-4). Third, together with WP3, we will co-define, develop and validate the daily EMA and EPA measures for stress detection (T3.1) as well as the JITAI (T3.3) for the police. All listed collaborations between WPA, WPB, and WP1-3 rely on simultaneous close interactions with the theoretical and ethical pillars (WPC), and the dialogue with societal partners (WPD) (e.g. to contextualize research questions). The novelty of the approach lies in the direct combination with WPB (youth at risk) and the combination of groundbreaking methods across the program.

Methodology

Target group: As professionals at risk we will recruit 200 relatively young police people that are either still at the police academy (level MBO- secondary vocational education) or already working as a police officer (Age 18-30). This will result in overlap in age with WPB to allow comparisons between age-matched individuals. In previous studies we showed that police recruits are exposed to many potentially traumatic events already during their training. On average during their police training they experience at least six different types of violence. This includes including finding a dead body form an accident or suicide, having to operate in situations of serious accidents, domestic violence etc[9]. We previously found that the magnitude to which police officers are exposed to trauma, scales with the chance to develop post-traumatic stress symptoms[87] and that neural (frontal) emotion control indices can predict long term resilience in this group of young police officers[9] and is linked to relatively low use of aggression[88]. We will assess under which conditions police officers will show hyper- or hypo-arousal of neurobiological and neurophysiological systems associated with suboptimal emotion regulation and develop interventions that promote effective emotion regulation that is personalized to the needs of police officers. Power: Following our previous work in police[9, 65] we use a sample size of N=200 in the observation study (TA.2) to give us the necessary power (80%) to detect even small neural effects (d = 0.2; with up to 20% dropout) and N=200 (of which 50 controls) for the intervention studies (TA.4), allowing to detect medium effects ($\boldsymbol{d}$ = 0.5; with up to 30% dropout). For TA.5 a homogenous group of 100 police officers is tested to link training effects to transfer tasks, this is conservative given earlier effects in 57 police officers[52].

Participatiory action research (PAR): Our assessments and interventions will be designed via the PAR and co-design method[23]. Based on our experience with the iterative process for game design together with first

responder target groups[44, 45].

Baseline emotion-regulation measurements: (1) Psychophysiological (HRV/HR), behavioral (observations and decisions) and subjective (stress-level, mood, sense of agency), using EMA/EPA (developed in WP3) assessed across four weeks. (2) (f)MRI paradigm co-developed withWP1 (stress induction and emotion regulation flexibility tasks) and one target group specific (approach-avoidance decision under threat task).

Intervention: After the baseline assessment, the total sample of 200 participants will be divided across an intervention (N=150) and control group (N=50). These sample sizes are sufficient for fMRI analyses based on prior sample size estimations in our labs[65].

Training: The *core training* consists of the closed-loop VR-based biofeedback training, in which police officers are first trained to up-regulate and down-regulate HRV and then apply it in an active action-decision context. We have recently developed and validated the basic training, proven to lead to transfer to VR-play without biofeedback and to real life scenarios[44, 45, 52]. We will - together with WP2 and the target group- adapt the VR-training to further optimize transfer to real life scenarios[44, 45, 52]. Based on individual training parameters, targets for the just-in-time-intervention (JITAI) will be selected and implemented with WP3. Pilot work indicates that we can use EMA and EPA using smartwatch-based technology with good compliance in groups at risk, including police officers[89, 90].

Outcome measures of training: (1) *Acute emotion regulation indices* are taken from psychophysiological (autonomic balance HRV/HR), behavioral (observations and decisions) and affective (stress-level, mood, sense of agency) indices during the training. (2) We will assess if these effects *transfer to real-life* scenarios and interactions and in daily life (EMI's developed in WP3). In addition, we will assess if these indices mediate effects of training on long term *mental health outcome* (stress-symptoms[9, 65]) and *professional skills* (self-reported and objective observations in TA.5).

Real life interactions: Real life interactions will be assessed in two contexts:

1) Police scenario's officer in operation (OVDP): A series of 6 standard role play scenarios applied before and after the intervention. We have piloted the setup of the study in a realistic simulation police practice village (Ossendrecht) where police officers undergo a standard training (OVDP).

2) *The permanent 'experience-exposition: Human Work (mens en werk)' at the Police Academy Apeldoorn*. This permanent exposition offers police officers as well as civilians the possibility to experience police-relevant situations in an immersive and engaging fashion. It offers the ideal situation to examine the impact of a self-awareness-raising VR biofeedback intervention on the quality and disclosures during real life interactions among police workers and between police officers and with youth. Small groups of people simultaneously go through this 'immersive experience exhibition' (curated with artists and rated well for engagement and interest), where they are immersed in 5 experiences relevant to the police: (1) extreme situations, (2) dealing with anyone and everyone, (3) dealing with violence, (4) colleagues and the organization, (5) the dying and death. Before and after the interactions, group discussions take place (See WPD) allowing for qualitative analyses (themes, word usage, self-disclosure, proximity) as well as quantitative analyses of HRV, positioning towards the group (distance).

TA.1: Recruitment, co-design and PAR with risk professionals (M1-M12) **Personnel:** PD3 (with WPD) **Partners involved: UvA**, UMCU, RU, UvH, Radboudumc

We will develop an impact pathway in co-creation with police officers (and youth), capitalizing on PAR and human centered co-design (throughout the entire empirical and design cycles), in order to attenuate and contextualize our research questions and research methods to their respective needs and goals[23]. Concretely, in collaboration with WPD, we will define which high stress environments require what type of HRV regulation in police officers. We will discuss this in two focus groups (N=8), each with 2 police officers from group1 (MBO), 2 police officers from group2 (OVDP), 2 police trainers and an education specialist of the police academy. Based on this we will define what kind of contexts elicit stress and aggressive escalations. This information will be fed into the police-specific fMRI task (WP1); the VR scenario (WP2), and the EMIs/JITAIs (WP3). Whereas pilot work with the police academy has already defined the need for HRV biofeedback training in target group 1 and 2, this task will further refine the exact scenarios.

TA.2: Assess contextualized emotion regulation paradigms in risk professionals using functional MRI to and in real life to identify subgroups (M13-M48) **Personnel:** PhD6, PhD7 and RA1 **Partners involved: Radboudumc**, EUR, RU

This baseline project will reveal the neural mechanisms and daily life psychophysiological, behavioral and

subjective dynamics during emotion regulation and decision under threat of police officers. Previous work indicated that this group of professionals at risk is highly heterogeneous in terms of stress-resilience and police performance[9]. We will unravel the variability in subgroups; a necessary step to understand who benefits from interventions and when. We will use the fMRI paradigms and the EMA/EPA measures co-developed with WP1 and WP3 respectively.

TA.3: Co-design closed-loop VR-based biofeedback and Just In Time Adaptive Interventions (M15-M24)
Personnel: PhD7, PhD8 Partners involved: RU, EUR, Radboudumc, UvH
In collaboration with WP2, we will apply an iterative 'design cycle' method, to co-design the 7-session VR-biofeedback intervention together with game designers and users (police officers) in a series of iterations[4–6]. In collaboration with WP3, we will use learning rates and strategies derived from existing pilot data in 50 police officers, using a beta version of the VR-Biofeedback game, to develop criteria on which we base the JITAI.

TA.4: Training effects on daily life measures (M38-68) **Personnel:** PhD4, PhD6 and PhD7 **Partners involved: RU**, Radboudumc, EUR
We will test the effects of interventions on flexible emotion regulation skills in acute situations and in the long run and in daily life (with WP3) in the 200 police officers from TA.2A. (150 will be allocated to the real intervention, 50 will be allocated to an active control condition without biofeedback). This also enables us to assess whether we can predict trainability from the neural measures taken at baseline in TA.2A (with WP1).

TA.5: Training effect on real life scenario's (Group 2) (M38-62) **Personnel:** PhD8 and PhD7 **Partners involved: UvH**, RU
In collaboration with WP2, we will test the effects of intervention on flexible emotion regulation skills in acute threat situations of the OVDP training groups (N=100) (50 with vs 50 without the biofeedback intervention).

TA.6: Assess transfer of bio-regulatory skills in real life *interactions* (M73-96) **Personnel:** PD2, PD4 **Partners involved: UvH**, AUMC, UMCU, RU
In collaboration with WPB and WPD, we will assess transfer of bio-regulatory skills to real life interactions in the context of the permanent 'experience-exposition 'human work' at the police academy. Members of police staff (N=8) will simultaneously undergo the VR training, after which they participate in a group discussion (30 mins). Together with WPC and WPD, and via an iterative process with target groups, we will draw up the questions the groups will talk about. They then go through the 'experience exhibition where they are immersed in 5 experiences relevant to the police (see methodology WPA), throughout which they will be monitored (EPA). After this, the second group conversation will take place (30 mins). Qualitative analyses (themes, word usage, self-disclosure, proximity) as well as quantitative analyses of HRV, positioning towards the group (distance) are measured. We will not only run 4 groups with police officers, but in order to investigate the effect of self-awareness training on how professionals and youth at risk experience violence relevant themes, in addition 4 groups of age- matched civilians and 4 mixed groups (50% police, 50% youth) will undergo the same procedure.

Productive interactions (co-design and co-creation)
This WP is specifically aimed to co-design all experimental procedures and interventions with recruits at the police academy and police officers at risk. We will thus involve individual recruits and officers in our focus groups. In addition, we will collaborate with GOMM, the Knowledge Centre People & Police of the Dutch National Police, who will contribute to co-design Study TA.5; PZP, the Police Care Fund including representation of police trade unions, together with the Central Works Council, will critically reflect on optimizing the training to enable implementation of the interventions into the current police education at various levels in the organization (MBO, bachelors); the Police Academy supports the focus groups with an in kind contribution, and their trainers and educational officer (e.g. Teun Pieter de Snoo, Police Academy Leusden) will participate in the focus groups. In addition, the Police Academy will help recruit for the studies.

Contribution to impact pathway
WPA will contribute to the project outputs as described under WP1-3 by ensuring the solutions developed match the needs of police officers and recruits as well as their trainers. Specifically, WPA ensures that research questions and paradigms are co-designed; insights are co-interpreted; and VR biofeedback and just in time adaptive interventions are co-designed with police. Thus, this WP contributes directly to **outcomes 3-6**.

Requested WP budget

Description cost/in-kind contribution	*Amount (€)*
Salary costs 2 Postdocs (1 year, 1 fte and 2 years, 1 fte)	285.979,-

Salary costs 3 PhD students (each 4 years, 1 fte)	913.917,-
Salary costs 1 Research Assistant (1 year, 0.5 fte)	41.965,-
Benchfee, travel and publication costs (3* 12.000, 1*7.500, 1* 10.000)	29.500,-
Participant reimbursement (incl. participant travel costs)	42.000,-
In kind contribution Police Academy for focus groups	29.616,-
Total	1.342.977,-

Motivation: The three PhD students will be involved in co-designing the assessments and training tools, as well as data collection in the two target groups of this WP. The PhD students all collaborate with another WP (1,2&3) for their specific tasks, neural measures (WP1), VR-based biofeedback-intervention (WP2); EMA/EPA/JIT (WP3). Postdocs are recruited for tasks that require more experience, such as refining high stress contexts, assessing the training-effects on real life scenarios (total 5 years needed). A Research Assistant (RA) is needed for help with data collection, to enable PhD students to focus more on setting up studies, data organization and analyses and writing. Note that costs for fMRI scanning, VR/biofeedback development, and EMA/EPA/JIT development are budgeted under the methodological WPs (1-3).

WP B: Youth at risk (M1-M96)

WP leader: Prof. Eveline Crone (Erasmus University Rotterdam)
WP personnel: PhD8 (with WPA), PhD9, PhD10, Postdoc5, Postdoc6, RA2
Participating applicants: Dr. Ilse van de Groep (EUR), Prof. Lucres Nauta-Jansen (AUMC), Dr. Carmen-Silva Sergiou (AUMC), Dr. Annelinde Vandenbroucke (AUMC), Prof. Karin Roelofs (RU), Prof. Erno Hermans (Radboudumc), Dr. Floris Klumpers (RU), Dr. Marta Marciniak (EUR)

Objectives

1. Youth participation action research (Y-PAR) in adolescents and young adults with police contact (rule-breaking behavior with the purpose of harming others (antisocial behavior) and ideology-driven (e.g., being arrested because of protesting)) to refine and contextualize the research questions on emotion regulation in high stress environments.
2. To test baseline mechanisms of emotion regulation using contextualized emotion-regulation paradigms (with WP1 on brain mechanisms) in youth with police contact
3. To test the dual loop intervention in youth with police contact, using closed-loop VR-based biofeedback (with WP2) and Just-in-Time Adaptive Interventions (JITAI) (with WP3), mirroring WPA.
4. To assess transfer of emotion-regulation skills in post-intervention lab sessions and in daily life variability.
5. To optimize bio-regulatory skills in real life interactions in participatory sessions across groups.

Approach and link to other WPs

This work package will focus on contextualized, co-designed assessment of emotion regulation mechanisms and rigorous testing of the effectiveness of the dual loop intervention in youth at risk. Because high-stake stress situations involving both youth and police are interpersonal, and to enable cross-pollination between work packages, this work package (youth at risk) is closely aligned with WPA (professionals at risk) and follows the same procedures and objectives. When conducting the study, WPB is intertwined with WP1, WP2 (T2.1-2) and WP3 (T3.1-3) for methodology development, psychophysiological, behavioral and neural assessment, and testing of the intervention components. First, together with WP1 and WPA, WPB will (1) co-develop the fMRI paradigms related to flexible action monitoring and prefrontal cortex hierarchy described in WP1 (see corresponding tasks T1.1-2), (2) subsequently assess the neural correlates of flexible emotion regulation in the youth target population using the same paradigm as WPA (T1.4), and assess whether these neural correlates predict intervention success in the youth target population. Second, together with WP2, we will (1) co-create youth-relevant virtual contexts (T2.1) and the biofeedback design (T2.2) for the first loop of the intervention, and (2) subsequently test the effectiveness of the biofeedback component of the intervention in the youth target population (T2.3-4). Third, together with WP3, we will co-define, develop and validate the daily EMA and EPA measures for stress detection (T3.1) as well as the JITAI (T3.3) for the youth target population.

All listed collaborations between WPA, WPB, and WP1-3 rely on simultaneous close interactions with the theoretical and ethical pillars (WPC), and the dialogue with societal partners (WPD) (e.g. to contextualize research questions). The novelty of the approach lies in the alignment with WPA (professionals at risk) thereby targeting two groups (professionals and youth at risk) that confront each other in real-life settings, and the combination of methods across the full program.

Methodology

Target groups: We will recruit N=200 youth with a history of police contact in the age range 16-24 years given that most often in this developmental period problems with emotion arise[91]. The frequency of emotion regulation problems are rising because of higher stress levels related to societal demands[92]. This is also the age range where intervention effects are expected to be highest [69]. We have experience with recruitment of youth with police contact in this age range[93].

Youth with a history of police contact represent a heterogeneous group in showing reactive aggressive rule-breaking behavior, sometimes combined with proactive antisocial and/or norm-violating behavior. Therefore, we expect that a more detailed measurement level that ranges from behavior, neurobiology and neurophysiology will lead to better insight in variability in emotion regulation[94]. We will test under which conditions youth with antisocial behavior will show both hyper- and hypo-arousal of neurobiological[14, 35] and neurophysiological systems[36, 94] associated with emotion regulation. Our design is therefore targeted to develop interventions that promote effective emotion regulation that is personalized to the needs of youth with a history of police contact.

Y-Participation action research (Y-PAR[23]): The baseline measure and intervention will be co-designed with youth based on participatory actions research methods in 3-5 groups including 6-8 youth each[23, 95]. This allows us to improve our designs and to align the approach with the needs of the target groups, which facilitates future adaptation of the results in policy making (together with WPC/D).

Baseline emotion-regulation measurements: (1) Psychophysiological, behavioral (observations and decisions) and subjective (stress-level, mood, sense of agency) (together with WP2 and WP3) across four weeks. (2) (f)MRI, including two general tasks designed in WP1 (stress induction and emotion regulation) and one youth specific task (approach/avoidance for youth) developed during the Y-PAR session and adapted together with WP1.

Intervention: In line with WPA, after the baseline assessment, the total sample of 200 participants will be divided across an intervention (n=150) and control group (n=50). These sample sizes are aligned with WP1&A (see power calculations above).

-The *core training* of the intervention consists of closed-loop VR-based biofeedback training, in which youth are first trained to up- and down-regulate HRV and then apply it in an active action-decision context. Together with WP2, the VR-training will be adapted from the existing training developed in WPA, proven to lead to transfer to VR-play with biofeedback and to real life scenarios. Based on individual training parameters, targets for the just-in-time adaptive intervention (JITAI) will be selected and implemented with WP3. Pilot work indicates that we can use EMA and EPA using smartwatch-based technology with good compliance in groups at risk (see WP3).

-Outcome measures of intervention: Across tasks in this WP, the following outcome measures will be assessed: 1) Psychophysiological, behavioral (observations and decisions) and subjective measures (stress-level, mood, sense of agency) during the training, during the real-life experimental scenarios and interactions and in daily life (WP3). 2) We will use the neural measures using fMRI before training, including two general tasks designed in WP1 (stress induction and emotion regulation flexibility) and one target group specific task (approach/avoidance) as predictors for intervention effects.

Real life interactions: Real life interactions will be developed in collaboration with WPA and will use the same procedures as those developed for professionals.

TB.1: Recruitment, co-design and Y-PAR (M1-M12) Personnel: PD5 **Partners involved:** EUR, AUMC

We will develop an impact pathway in co-creation with youth with police contact (together with WPD), capitalizing on Y-PAR (throughout the entire empirical and design cycles; in order to attenuate and contextualize our research questions and research methods to their respective needs and goals[23]. This project aims to clarify which high-stress environments are most promising for experiential learning through VR-biofeedback training for youth (together with WP2 (T2.1 Game design), WPC, WPD). Next to the perspectives, goals and needs of youth, in the impact pathway we will also consider potential supportive and conflicting perspectives, needs and goals of other stakeholders (i.e., multi-objective stakeholder design and multi-objective personalization, together with WPC/D, WPB), to optimize the application of the intervention (objective 5, together with WPB).

TB.2 Assess mechanisms of contextualized emotion-regulation in youth with police contact using functional MRI to identify subgroups (M13-M60) Personnel: PhD8&9 **Partners involved: EUR**, RU, Radboudumc

This baseline project will provide more understanding of the neural and psychophysiological mechanisms of youth who are involved in aggression acts and experience police contact. This group is highly heterogeneous but differs in the extent to which they have an adverse impact on society. Adolescents and young adults choose their goals in increasingly independent ways and there are multiple underlying reasons for rebellious acts. This project will unravel the variability in subgroups; a necessary step to understand who benefits from interventions and when. The project will make use of the fMRI paradigms developed in WP1 and a set of co-designed behavioral measures targeted at emotion regulation in an individual, social and societal context. This project consists of longitudinal measures in the control groups of this program.

TB.3 Assess mechanisms of contextualized emotion-regulation in youth with police contact using variability (brain variability, EMA/EPA) to predict flexibility (M13-M60) **Personnel:** PhD10 **Partners involved: EUR**, RU, Radboudumc

This task will provide a detailed understanding of within-person variability in emotional states. Youth who are in contact with the police differ in their states of emotional reactivity and are not all antisocial. Adolescents with antisocial tendencies usually choose goals that are more short-term and give little value to consequences for others, but there is a need for better understanding of the changing arousal states in daily life. This project will make use of baseline measures of variability (brain variability and EMA/EPA mood variability) as a predictor for intervention effects. This project makes use of the baseline and outcome measures.

TB.4 Test effects of the intervention in youth with police contact (M61-M84) **Personnel:** PD6 **Partners involved: EUR**, RU, AUMC

This task tests the full dual-loop intervention effects using the data acquired in M13-M60 using baseline and follow up measures and using individual intervention effects. The additional goal of this project is to contextualize the results in participatory sessions including youth with police contact and police professionals within the goals of the impact pathway[23].

Productive interactions (co-design and co-creation)

Co-design is guaranteed through our societal partners. Albeda MBO and Hogeschool Rotterdam will be involved in the initial stages of co-design. MIND US and SLM will provide youth perspectives in the context of societal demands on youth. iHUB and Fivoor will provide input from a specialized youth mental health care perspective during the initial stages of co-design and when the interventions are tested in youth with police contact. Yope will be involved throughout all stages of co-design to provide youth perspectives based on lived experience. HALT will be involved in the initial stages of co-design, to facilitate recruitment and when the interventions are tested in youth with police contact. Levvel (forensic youth care) is involved in the initial stages of co-design, to facilitate recruitment and when interventions are tested in youth with police contact.

Contribution to impact pathway

WPB will contribute to the project outputs as described under WP1-3 by ensuring the solutions developed match the needs of youth at risk and youth (forensic) care workers. Specifically, WPB ensures that research questions and paradigms are co-designed; insights are co-interpreted; and VR biofeedback and just in time adaptive interventions are co-designed with youth and youth workers, contributing to **outcome 7**.

Requested WP budget

Description cost/in-kind contribution	*Amount (€)*
Salary costs for 2 PhD students (each 4 years, 1.0 fte)	609.278,-
Salary costs for 2 Postdocs (1 year, 1.0 fte; and 2 years, 1.0 fte)	285.979,-
Benchfee, travel and publication costs (2* 12.000, 1*7.500, 1* 10.000)	29.500,-
1 Research Assistant (1 year, 0.5 fte)	41.965,-
Participant reimbursement (incl participant travel costs)	42.000,-
Total	1.008.722,-

Motivation: The budget includes a one year post doc to guarantee cross-talk between sites and to develop participatory driven research designs during M1-12 (task TB.1). A two-year post doc will analyze the final data dual-loop intervention results in youth during M61-84 (task TB.4). Two PhD students will collect the pre-post data during M13-M60 for tasks TB.2 (i.e. assess mechanisms of contextualized emotion-regulation in youth with police contact using functional MRI to identify subgroups) and TB.3 (i.e., Assess mechanisms of contextualized emotion-regulation in youth with police contact using variability (brain variability, EMA/EPA) to predict flexibility). One research assistant will assist with the intervention under the guidance of WP 2-3. Note that costs for fMRI scanning, VR/biofeedback development, and EMA/EPA/JIT development are budgeted under the methodological WPs (1-3).

WP C: Mathematical theory and ethical analysis (M1-M24 and M73-M84)

WP leader: Dr. Willem Frankenhuis (University of Amsterdam)
WP personnel: Postdoc7, Postdoc8, Postdoc9
Participating applicants: Dr. Karin Jongsma (UMCU), Dr. Katherine Bassil (UMCU)

Objectives

1. To clarify the meaning of "optimal" emotion regulation, and "optimization" of biofeedback, through conceptual analysis and review of literature across the biological and social sciences.
2. To build novel mathematical models of adaptive emotion regulation, to examine which strategies and levels of regulation are beneficial depending on an individual's internal state and external environmental context.
3. To ethically evaluate the implementation of biofeedback for optimal emotion regulation for different target groups, including short-term and long-term implications.
4. To formulate design requirements and implementation guidance for the use of biofeedback in the prospective target groups.

Approach and link to other WPs

What is "optimal" emotion regulation? How should people control their emotional state? Does the optimal level maximize well-being, health, education, or social relationships? What if benchmarks conflict with each other? Can we apply the same benchmark to all individuals, or does the optimal level depend on individual and contextual factors? These basic questions underpin assumptions guiding research and interventions on optimal emotion regulation. They need to be addressed for research and interventions to have the desired scientific and societal impact.

We will take a two-pronged approach: mathematical theory and ethical analysis, acting synergistically. We will focus on three questions: How do theories across disciplines conceptualize optimal emotion regulation (e.g., the definitions used)? Which normative benchmarks do these theories use (e.g., what is good for the individual vs. society, well-being vs. biological survival)? How do we determine, in a formalized way, which strategies and levels of emotion regulation are optimal for a particular individual in a specific context? The term 'context' here refers to environmental exposures to threat (i.e., physical or psychosocial harm imposed by others), deprivation (i.e., low quantity and quality of social and material resources), and unpredictability (i.e., random variation in exposures to threat and deprivation across space and time.

This WP undergirds the other WPs by: (1) clarifying theory and concepts, (2) co-constructing research aims (see also WPD), (3) providing predictions for experimental EMA studies (see WP3), and (4) offering ethical guidance to intervention design and implementation.

Methodology

The theoretical analysis will clarify concepts, compare theories, and formalize "optimal" emotion regulation. Clarifying concepts involves analyzing notions of optimal emotion regulation used across the biological and social sciences (e.g., cognitive neuroscience, development science, mental health, organizational psychology, behavioral biology). Comparing theories involves analyzing the normative benchmarks assumed by theories of optimal emotion regulation. Formalizing optimal regulation involves using existing[72, 96-98], and building novel, mathematical models to understand and predict individual differences in optimal strategies and levels of emotion regulation (e.g., baseline, reactivity, and recovery) depending on current (internal) physiological state and (external) environmental context[71, 72]. We will develop one set of mathematical models prior to data collection, and another set post data analysis, to incorporate lessons learned from the empirical analyses.

The ethical analysis will be performed by applying ethics-parallel research[70] to identify and evaluate the ethical and societal implications of the implementation of biofeedback for emotion regulation. By actively including ethicists and end-users (including professionals and the youth), identifying unique perspectives and needs, including individual differences, through qualitative research, we can collaboratively shape research and implementation aims (see also WPD). This approach ensures that these technologies are guided in a desirable direction, during development, as well as before and throughout implementation. In this project we therefore go beyond technical feasibility and put explicit efforts in investigating the conditions under which foreseen users consider these technologies desirable and acceptable. These insights allow to formulate normative guidance for scientists, ethicists, and developers.

Together, our methodologies act synergistically by providing theory- and ethics-based guidance in the design, implementation, and evaluation of experimental studies and biofeedback interventions in different contexts and for different target groups.

TC.1: Mapping and comparing concepts and theories of "optimal" emotion regulation (M1-M24) **Personnel:** PD7, PD8 **Partners involved: UvA**, UMCU

In the wake of the replication crisis, there have been many initiatives to increase transparency in psychological research (e.g., preregistration, sharing materials, data, and code). These initiatives promote reliable and reproducible findings[99, 100]. However, stronger empirical bricks are not enough; we need solid theory to build the house. TC.1 will advance current theory by clarifying concepts (conceptual analysis) and comparing theories in terms of their normative benchmarks (ethical analysis), and TC.1 by developing novel theory. We will conduct a systematic review of literature across the biological and social sciences using the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[101]. To do so, we will search the Web of Science Core Collection database. We will develop a classification scheme for different notions of optimal emotion regulation, and a classification scheme for the normative benchmarks that theories assume. These classification schemes will increase conceptual clarity in the scientific literature generally, and inform our experimental studies, participatory research, and biofeedback interventions.

TC.2: Mathematical theory to understand and predict individual differences in "optimal" emotion regulation depending on physiological state and environmental context (M1-M24) **Personnel:** PD7 **Partners involved: UvA**

To improve our understanding and guide key predictions about optimal emotion regulation, we will develop novel mathematical theory. To date, most theories about how environmental contexts influence emotion regulation are stated in verbal language, which is ambiguous (i.e., open to multiple interpretations) even if carefully crafted. By expressing a theory in mathematical terms, we make all concepts, assumptions, and reasoning explicit. The art of modeling is to capture essential features. Our models will characterize the functions of emotion regulation in terms of 'benefits' and 'costs'. Specifically, they will distinguish between "fast-but-inaccurate" and "slow-but-accurate" systems. The slower system requires parasympathetic regulation and is relatively flexible: it integrates more information, generates more diverse solutions, and affords more behavioral options. However, to do so, it needs more resources (e.g., time, energy). By contrast, the faster system is predominantly sympathetic driven and well equipped for fast fight/flight reactions with relatively fewer resources. We will explore how individuals should balance the use of these two systems depending on their physiological state and environmental context (both of which are changing through time). We will use state-dependent optimality theory[102-105] implemented by stochastic dynamic programming, to investigate which strategies and levels of emotion regulation are optimal for a particular individual in a specific context.

TC.3: A revised mathematical model based on the empirical lessons learned (M73-M84) **Personnel:** PD9 **Partners involved: UvA**

In TC.2, we proposed to develop novel theory to guide our data collection. By contrast, in TC.3, we will use the research findings of our empirical WPs to guide theory revision. In the spirit of open science, theory revision is best done transparently, rather than by exploiting ambiguities in the original formulation of the theory[99]. Formal modeling is well-suited to transparently revising theory based on empirical data, as both the original theory (TC.2) and the revised theory (TC.3) are specified in mathematical terms. Thus it is explicit how assumptions are being modified, and what the implications are of these modifications for modeling results and predictions. Although it is not possible to exactly specify a priori *how* we will revise model assumptions—the aim is, after all, to revise based on lessons learned from to-be-collected empirical data—we will likely include a moderator of emotion regulation (e.g., fatigue) that changes in a fixed manner during the day or dynamically as a function of an individual's state (e.g., hunger). The EMA observational data from youth is the relevant source of data for this revision, because it includes repeated measures of environmental context, emotion regulation, and potential moderators, represented as time series data, analogous to the model variables. Together, TC.2 and TC.3 form a cohesive ensemble.

TC.4: Identification of ethical implications of optimizing emotion regulation (M1-M24) **Personnel:** PD8 **Partners involved: UMCU**

Optimal emotion regulation is the ability to effectively manage and respond to emotional experiences according to some normative benchmark. "Optimal" refers to the most favorable, effective, or efficient outcome in a given situation. In the context of emotion regulation, "optimal" means achieving the best possible result that maximizes a certain outcome (or behavior) while minimizing negative outcomes. However, these benchmarks are context-dependent and may not be representative of all groups. Seeking a

standardized approach to emotion regulation for instance could lead to ethical challenges, as it may overlook individual preferences, cultural differences, and the right to personal agency in managing emotions. To identify the ethical and societal implications associated with seeking "optimal" emotion regulation among high-risk individuals (i.e., professionals and youth), we will conduct a literature review. A literature review will allow us to scoop for available theoretical and empirical discussions on the ethical and societal impact of emotion regulation. As a consequence, we can identify so-called 'hard and soft impacts' of the intervention. Hard impacts are measurable and quantifiable impacts of a technology, often described as risk, side-effects, safety, and therapeutic value. However, hard impacts are not the only way a technology may influence people at the individual and collective level. Soft impacts are the effects of a technology or intervention on behavior, experiences, actions, moral values, and social structures, among others.

TC.5: Develop ethical guidelines and recommendations (M12-M24) **Personnel:** PD8 **Partners involved: UMCU**

To ensure ethical and responsible implementation of biofeedback applications for emotion regulation, we will synthesize the findings of our theoretical and ethical analysis (TC.1-4) and focus groups (WPD, TD.1) and propose guidelines and recommendations for the implementation of this intervention for stakeholders such as the Police Academy, (forensic) youth psychologists, and management. By incorporating these insights, we can establish empirically-informed and theoretically robust ethical guidelines that bridge theoretical frameworks with practical, context-sensitive definitions of optimal emotion regulation, for all users, especially high-risk individuals.

Productive interactions (co-design and co-creation)

This WP will gather feedback on the theoretical and ethical analysis by engaging with all stakeholders in the Stakeholder Forum, to ensure that the ethical guidelines and recommendations are practical and in line with scientific advancements and societal expectations.

Contribution to impact pathway

WPC provides a novel ethics framework on biofeedback technology for emotion regulation for the responsible development and implementation in specific target groups. This will not only contribute to **outcomes 4-6** (police) and **7** (youth), but also to future scientific research (**outcomes 1-2**). WPC will also advance interdisciplinary theory on emotion regulation and build novel formal models to better understand the adaptive benefits and costs of higher and lower levels of emotion regulation, depending on environmental context. This will directly contribute to **outcome 1**.

Requested WP budget

Description cost/in-kind contribution	*Amount (€)*
Salary costs Postdocs (2*2 years, 1*1 year, 1 fte)	497.904,-
Benchfee, travel and publication costs (2* 10.000 and 1* 7.500)	27.500,-
Transcription costs	5.000,-
Total	530.404,-

Motivation: One postdoc will conduct the ethics literature review (TC.4), plan and conduct the focus groups (in collaboration with WPD) followed by analyzing the results, and finally perform the ethical analysis that will contribute to the ethics guidelines (TC.5). Another postdoc will conduct the systematic review of literature, and conceptualize, program, and interpret the results of the initial mathematical model (TC.2). We will recruit a postdoc with a background in computational psychology, computer science, mathematics, or physics. The third postdoc will conceptualize, program, and interpret the results of the revised mathematical model based on the empirical lessons learned (TC.3). This postdoc will also help to compute indices of environmental unpredictability based on the empirical data, analogous to variables in the formal models. We will recruit a postdoc with a background in computational psychology, computer science, mathematics, or physics.

WP D: Impact (M1-M96)

WP leader: Prof. Lucres Nauta-Jansen (Amsterdam UMC)

WP personnel: PD2 (with WP3 and WPA and B), PD10 (with WPC), knowledge broker

Participating applicants: Dr. Annelinde Vandenbroucke (AUMC), Dr. Carmen-Silva Sergiou (AUMC), Prof. Eveline Crone (EUR), Dr. Ilse van de Groep (EUR), Prof. Karin Roelofs (RU), Dr. Floris Klumpers (RU), Prof. Annika Smit (UvH), Dr. Karin Jongsma (UMCU), Dr. Katherine Bassil (UMCU), Dr. Marta Marciniak (EUR), Prof. dr. Erno Hermans (Radboudumc), Dr. Florian Krause (Radboudumc), Dr. Willem Frankenhuis (UvA)

Objectives

1. Refine and contextualize the research questions on emotion regulation in high stress environments, based on needs and feasibility of police, youth and societal partners through Participation Action Research (PAR)
2. Develop and update a roadmap to implementation of interventions with stakeholders
3. Evaluate the use of interventions in police academy and (forensic) youth care
4. Share knowledge with stakeholders
5. Assure sustainability of the program

Approach and link to other WPs

The impact work package aims to create a societal impact by guaranteeing that the knowledge and interventions as developed within the CONTEXT project match the needs of all stakeholders, including professionals and youth at risk. WPD will help to achieve this by including stakeholders throughout the project. Stakeholders will be involved in refining and contextualizing research questions, research methods, interventions, educational modules and implementation plans based on their needs.

This WP will closely collaborate with all other work packages to:

- adapt assessments and interventions to the specific needs of stakeholders (WP1-3)
- take into account the contexts and needs of the specific target groups professionals and youth at risk) as well as stakeholders such as the police and police academy, and forensic youth care and higher professional education institutions. This allows us to improve our designs and to align the approach with the needs of the target groups, which facilitates future adaptation of the results in practice and policy making (WP A and B).
- contextualize research questions and models, including ethical considerations (WPC), and with the neuroscience and intervention work packages (WP1-3).

Together, we aim to lay a strong foundation for implementation of the interventions and educational programs that will be developed within this project.

Methodology

Focus groups will be organized at the start (M1-12), regarding contexts and needs of stakeholders and target groups (in collaboration with WPC, WPA and WPB). These will inform the other WPs, also regarding optimization of research aims. Focus groups will consist of representative groups of 6-8 individuals from target groups (professionals at risk, youth at risk) and from stakeholders (police, police academy, youth care institutions, Halt, judicial institutions). 3-5 focus groups per target group will be organized. Together we will define the goals and needs for emotion regulation interventions.

Co-creation of assessments and interventions with police and youth will be done together with WPA, WPB, WP1, WP2 and WP3 (M1-24). Our assessments and interventions will be co-designed with youth and professionals based on Participation Action Research (PAR) methods[23]. This allows us to improve our designs and to align the approach with the needs of the target groups, which facilitates data collection as well as future adaptation of the results in implementation of the intervention and policy making. In addition, to be able to create impact from the start of the program, we will design educational material regarding emotion regulation during high-stress encounters, both from the perspective of police-officers, as well as from that of youth.

To successfully implement the intervention designed in WP2 and 3, and the educational module designed in WPD, we will use the Lippit-Knoster model (1991) to create an implementation roadmap (M73-96). The Lippit-Knoster model consists of 5 key elements (vision, consensus, skills, incentives, resources and action plan) that need to be defined together with stakeholders to successfully manage a project. Our vision is to create an innovative solution that enhances emotional resilience shared by academic experts and societal stakeholders.

In the last two years (M73-96), we will evaluate the interventions using a translational research cycle: analyze-translate-implement-monitor-evaluate (together with all work packages). In addition to testing the effects of the intervention in WPA and B, we will evaluate the theoretical model (in collaboration with WPC), procedural aspects and experiences of target groups and stakeholders (in collaboration with WPA and B). Specifically, with WPC, we will (a) evaluate which modeling predictions align with EMA data and which ones not, and (b) determine revisions that will enable the model to reproduce non-predicted patterns, and thereby enhance our understanding of the EMA data. This will be done to ensure maximal impact, sustainability, and dissemination of the platform to relevant stakeholders and institutions.

Finally, we will explore possibilities for professional exploitation to manage and monitor the CONTEXT-developed interventions and educational modules in the future.

TD.1: Identify stakeholder needs and define goals, and implementation outcomes (M1-M24) **Personnel:** PD10 **Partners involved: AUMC**, Radboudumc, EUR, UvA, UMCU

Optimal emotion regulation may mean different things for professionals at risk compared to then for youth at risk, different individuals and within the different contexts they encounter. To identify the individual perspectives and needs of different end-users (i.e., professionals and youth at risk) and ensure the successful implementation of the intervention, we will organize focus groups. This in turn will aid in refining goals and laying the foundation for the implementation roadmap. With this approach, we can identify stakeholder-specific needs and perspectives, in addition to hard and soft impacts (WPC, TC.4) of biofeedback for emotion regulation in different subgroups, and bridge the theoretical and ethical aspects (WPC) of what constitutes "optimal" emotion regulation.

TD.2 Co-Design of assessments and interventions with police and youth at risk (M1-M24) **Personnel:** PD10, knowledge broker **Partners involved: AUMC**, Radboudumc, EUR, UvH

Our assessments and interventions will be co-designed with youth and professionals at risk, in collaboration with WPA and B. This allows us to improve our assessments methods and interventions to align with the needs of the target groups. In this task we will also develop the educational modules regarding emotion regulation to be used within police academies, in addition to/preceding emotion regulation interventions.

TD.3 Share existing and new knowledge through meetings, symposia and media (M1-M96) **Personnel:** knowledge broker, all PIs **Partners involved: AUMC**, RU, Radboudumc, EUR, UvA, UMCU, UvH

Throughout the project, we will share existing and acquired knowledge through regular meetings with the consortium partners, general symposia and varying media outlets. This will be done in collaboration with all other WPs. To realize optimal impact, we will create a CONTEXT Impact Narrative using the Impact Narrative Tool (created by Convergence, Nederlands Centrum Jeugdgezondheid and Healthy Start). The Impact Narrative Tool is a tool that helps to involve and engage stakeholders, convey our message to a wider audience and account for the results of this project in a transparent way (www.impactnarrative.nl).

For this specific task, a knowledge broker will be appointed, who will closely collaborate with all consortium partners and WPs.

TD.4 Evaluate intervention theory, goals and outcomes (M24-M84) **Personnel:** knowledge broker, PD2 **Partners involved: AUMC,** RU, Radboudumc, EUR, UvH, UMCU

This task involves the evaluation of the interventions from a translational research perspective. In addition to testing the effects of the intervention in WPA and WPB, we will also evaluate practical aspects and experiences of target groups and stakeholders. Co-creation sessions will be conducted with cooperation partners at Levvel (forensic youth care), Young Perspectives (Yope), the Police Academy, Bureau Halt, and iHUB (specialized education and specialized youth mental care). The results developed in WPs 1-3/A-B will be combined in an optimal fashion into a new umbrella theory on emotion-regulation in high stress contexts. The PIs will devote 0,1 fte research time and will organize hackathons with early career researchers, impact conferences with societal partners and writing weeks for in depth analysis and theory development. This will lead to two products: an impact tool for societal outreach and a comprehensive review with a novel theory leading the way for scientific advancements in the areas of prevention, intervention and a better understanding of individualized needs.

TD.5 Implement the VR intervention in police and youth care (M60-M96) **Personnel:** knowledge broker, PD2 **Partners involved:** AUMC, RU, Radboudumc, EUR, PA

In this final part, the roadmap to implementation will be finalized and we will start with implementing the findings and resulting interventions. Here, we will also explore possibilities for professional exploitation to manage and monitor the interventions and educational modules in the future.

TD.6 Develop an overarching theory and impact tool (M85-M96) **Personnel:** PIs **Partners involved:** all

The results developed in WPs 1-3/A-B will be combined in an optimal fashion into a new umbrella theory on emotion-regulation in high stress contexts. The PIs will devote 0,1 fte research time and will organize hackathons with early career researchers, impact conferences with societal partners and writing weeks for in depth analysis and theory development. This will lead to two products: an impact tool for societal outreach and a comprehensive review with a novel theory leading the way for scientific advancements in the areas of prevention, intervention and a better understanding of individualized needs.

Productive interactions (co-design and co-creation)

This WP depends critically on input from all stakeholders. Both youth and police, as well as police academy and (forensic) youth care organizations are involved directly to co-define the goals for the interventions, and implementation thereof, in collaboration with WPA, B and C, and WP1-3. Co-creation sessions will be

conducted with cooperation partners at the Police Academy for professionals at risk, also in collaboration with the permanent 'experience-exposition: Human Work' at the Police Academy Apeldoorn (with the National Police, GOMM, PZP, CWC and individual police recruits and officers). As for youth at risk and youth care workers, co-creation session will be organized in collaboration with YOPE (Young Perspectives, experienced expert youth organization), MIND Us and SLM (youth participation organizations), Halt (diversion program for youth with police contacts), Levvel (forensic youth care), Fivoor (psychiatric care) and iHUB (specialized education and specialized youth mental health care). The roadmap for future implementation is co-designed by all stakeholders mentioned above, and additionally with stakeholders from education (HR, Albeda), psychotherapists (Arq), policy (MinDef, Emmen), health insurance (PZP), and other groups of first responders (military police, security).

Contribution to impact

This WP is dedicated to creating impact by guaranteeing that the results of the project, and the intervention in specific, matches the needs of both youth and professionals at risk; continuously involving all stakeholders, in order to develop an intervention and accompanying educational products that meets the needs of all stakeholders; developing a realistic implementation plan; and disseminating the knowledge and results from the project. Eventually, this will help achieve **all expected outcomes** and contribute to creating societal impact of the project, in reducing both the prevalence of aggressive incidents as well as decreasing the mental health implications for both professionals and youth. It will specifically contribute to **outcomes 8 and 9**.

Requested WP budget

Description cost/in-kind contribution	*Amount (€)*
Salary costs 2 Postdocs (each 2 years, 0.8 fte)	339.080,-
Benchfee, travel and publication costs (2*7.500)	15.000,-
Salary costs knowledge broker (8 years, 0.4 fte)	295.146,-
Knowledge products, meetings, symposia	109.500,-
Total	758.726,-

Motivation: 1 postdoc will be appointed during the first two years, for qualitative research regarding contexts and needs and refine research aims. 1 postdoc will be appointed for the last 2 years to evaluate the intervention and implementation thereof in practice. A knowledge broker is needed throughout the project to coordinate internal and external communication. Knowledge products include educational modules, knowledge clips, etc. Meetings include Stakeholder Forum meetings and co-creation meetings.

5.2 Planning

		Year 1				Year 2				Year 3				Year 4				Year 5				Year 6				Year 7				Year 8			
WP/task	**Personnel***	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96
WP1 Neural underpinnings of flexible emotion reg.																																	
T1.1 Develop experimental model	PhD1,2																																
T1.2 Identify optimal physiological states																																	
T1.3 Immediate effects biofeedback training																																	
T1.4 Neural correlates affective reactivity																																	
T1.5 Neural correlates intervention success																																	
WP2 VR/biofeedback																																	
T2.1 Game design	PhD3, *PhD4,* game designer, unity progr.																																
T2.2 Biofeedback design																																	
T2.3 Small-N assessment																																	
T2.4 Randomized controlled trial																																	
T2.5 Biofeedback computational modeling																																	
WP3 Just in Time adaptive interventions																																	
T3.1 Develop EMA/EPA measures	PhD5, PD1, *PD2*																																
T3.2 Develop stress detection algorithm																																	
T3.3 Develop EMIs for target groups																																	
T3.4 Integrate and test JITAI platform																																	
T3.5 Evaluate platform for dissemination																																	
WPA Professionals at risk																																	
TA.1 Recruitment, co-design and PAR	*PhD4,* PhD6,7 *PhD8, PD2,* PD3,4, RA1																																
TA.2 Assess contextualized emotion reg.																																	
TA.3 Co-design VR biofeedback and JITAI																																	
TA.4 Training effects on EMA/EPA																																	
TA.5 Training effects on real-life scenarios																																	
TA.6 Transfer of skills in interactions																																	
WPB Youth at risk																																	
TB.1 Recruitment, co-design, and Y-PAR	*PhD8,* PhD9,10 PD5,6, RA2																																
TB.2 Assess contextualized ER (fMRI)																																	
TB.3 Assess contextualized ER (EMA/EPA)																																	
TB.4 Test intervention effects																																	
WPC Mathematical theory and ethical analysis																																	
TC.1 Concepts and theories of 'optimal' ER	PD7,8,9																																
TC.2 Mathematical theory indiv. differences																																	
TC.3 Revised mathematical model																																	

TC.4 Ethical implications of optimizing ER		
TC.5 Ethical guidelines and recommendation		
WPD Impact		
TD.1 Identify stakeholder needs and goals	*PD2*, PD10, knowledge broker, all PIs	
TD.2 Co-design assessments & interventions		
TD.3 Share existing and new knowledge		
TD.4 Evaluate intervention goals		
TD.5 Implement intervention		
TD.6 Develop impact tool		

* italic = shared personnel across multiple WPs

5.3 Risk management and contingency plan

Table 6: *Risks and mitigation*

Risk	Likelihood	Severity	Mitigation
Intervention non-adherence (e.g. due to a too high burden for participants, lack of user-friendliness of the EMI, or lack of interest)	low	medium	The EMIs will be co-designed with the end-users from both populations and with various stakeholders to ensure that they are user-friendly, relatable, engaging, and acceptable to the users. In addition, any issues related to low adherence to the EMIs will be detected already in the pilot studies and thus, can be addressed accordingly by adapting the content of EMIs at the early stage.
Low EMA / EPA compliance in target populations	medium	medium	The EMA questionnaires will be co-designed with end users and other stakeholders to ensure that they are acceptable to the users. We will focus on brief questions, assessing only the key stress-related factors of lived experience. Any issues related to low adherence to the EMA/EPA will be detected already in the pilot studies and thus can be addressed by adapting the EMAs or EPA setup at an early stage. Experience shows that police officers are relatively compliant: in a large longitudinal study with repeated neuroimaging and online assessments we achieved 90% even at follow up. We acknowledge that this can be more challenging in youth but will focus on this risk starting at the earliest stage of co-design.
Technical issues related to coupling of the sensors and the online platform for individualized feedback	low	medium	The consortium has extensive experience in technology for coupling sensors to a real-time analysis platform[73], active collaborations with an open-source platform development community (https://radar-base.org), and connections to industry partners (e.g., https://www.thehyve.nl) for software development support.
Privacy breaches	low	high	The consortium is aware that data collected can be of a highly privacy-sensitive nature. However, consortium partners are highly experienced in (international and/or multi-center) data acquisition in various patient groups and/or healthy volunteers and therefore all procedures for eliminating this risk are already in place (see Section 6 for details).
Recruitment Police officers	low	high	The consortium has published experience with recruiting large groups of young police officers in training for neuroscientific studies from different locations throughout the Netherlands[9]. When there are changes in one curriculum. If the intake is disappointing, we will recruit at the bachelor level.
Recruitment Youth	Low	high	The consortium also has proven experience in recruiting at-risk youth for research. If recruitment progresses more slowly than expected, we can leverage our extensive network in the Netherlands to expand recruitment channels and intensify recruitment efforts (e.g., through advertisement).
Difficulties in implementation	medium	medium	We aim to mitigate this risk by involving stakeholders throughout, and co-designing the interventions with youth, police, as well as youth care professionals.

6. Data management

1. Will data that is collected or generated be suitable for reuse?

Yes

2. Where will the data be stored during the research?

All collected data, including self-reported questionnaires, behavioral data, physiological data, ecological momentary assessments, and MRI neuroimaging data, will be securely stored on Radboud University and Erasmus University Rotterdam servers in the responsibility of consortium coordinator. Data storage and processing will fully comply with the General Data Protection Regulation (GDPR) and relevant European Union regulations to ensure participant privacy and data protection. Explicit mention of these data handling procedures will be included in the consent forms provided to all participants.

3. How will the data be stored for the long term and made available for use by third parties when the project has been completed? For whom will the data be accessible?

After the study is completed, the anonymized data will be shared in a public repository, such as the Open Science Framework (OSF), in line with our commitment to open science. Participants will have the right to request data deletion up until the point when their data has been fully anonymized, i.e., ten years after completion of the project. Digital documents containing anonymized participant data will be encrypted at the site where they are originally obtained, and transfer of such data between sites will be done over secured servers. This will ensure that the data are accessible to the research community for future analyses, replication studies, and further scientific exploration, while maintaining participant privacy and compliance with GDPR and EU regulations.

4. What facilities (ICT, (secure) archive, refrigerators or legal expertise) do you anticipate will be needed for the storage of data during and after the research? Are they available?*

For the storage of data during and after the research we have Standard Operating Procedures in which several key facilities will be required. First, secure ICT infrastructure will be essential, including encrypted servers at Radboud University and Erasmus University Rotterdam, where anonymized data can be safely preserved and later shared in public repositories like the Open Science Framework (OSF). We have dedicated data officers (who consult with legal staff if needed) available at both sides. For biosamples, secured refrigerators and freezers are in place at both Radboud University and Erasmus University Rotterdam.

**ICT facilities for data storage are considered to be resources such as data storage capacity, bandwidth for data transport and computing power for data processing.*

7. Ethical aspects

	Not applicable	**Not yet applied for**	**Applied for**	**Received**
Approval from a recognised (medical) ethics review committee	☐	☒	☐	☐
Approval from an animal experiments committee	☒	☐	☐	☐
Permission for research with the population screening Act	☒	☐	☐	☐

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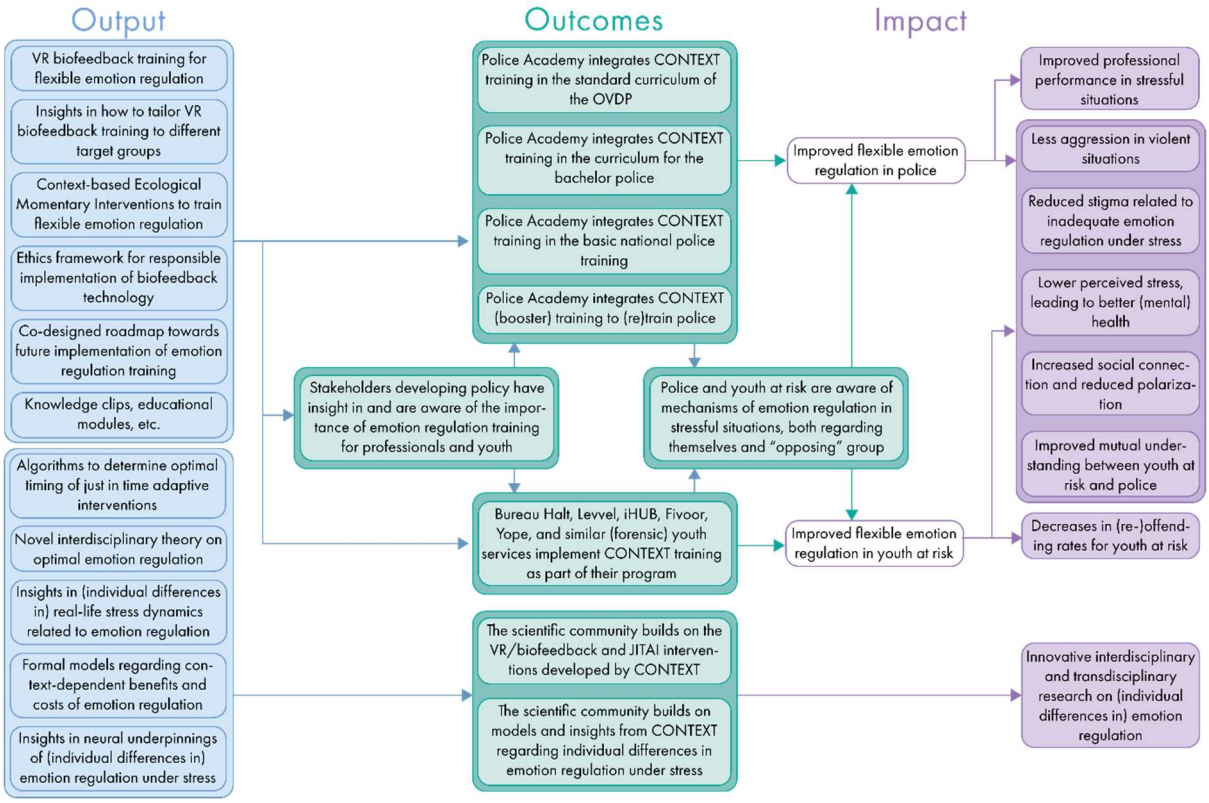
Annexes

A. Diagram Impact Pathway



B. Impact Pathway indicators

Output	Indicator
Novel insights regarding the neural underpinnings of (individual differences in) emotion regulation under stress	Scientific publications (>5) showing newly developed task for flexible emotion regulation under stress, individual differences in autonomic balance and real-life affective reactivity related to neural correlates of emotion regulation & effect of personalized biofeedback on neural correlates by M96.
Engaging and arousing VR biofeedback trainings to train flexible emotion regulation	2 versions of the VR biofeedback game, tailored to each target group to optimize individuals' ANS control, ready in M36 and updated by M96 after rigorous evaluations in RCTs.
Insights in how to tailor VR biofeedback training to different target groups	At least 4 publications regarding VR design & design of biofeedback in each group by M72.
Novel insights on (individual differences in) real-life stress dynamics and physiological aspects related to emotion regulation	At least 4 publications regarding real-life physiological and subjective stress dynamics, development of tools to assess real-life contexts characteristics + predictive modelling in each target group by M72.
Advanced algorithms to determine optimal timing of just in time adaptive interventions based on wearable information	At least 2 publications regarding algorithm development in each group by M48. The algorithms will be made publicly available.
Engaging and context-based Ecological Momentary Interventions (in 2 different versions for police and youth) to train flexible emotion regulation	Ecological Momentary Interventions ready by M36 for use in each group, evaluated in RCT by M72. Scientific publications (>4) regarding RCT by M96
A novel ethics framework on biofeedback technology for emotional regulation for the responsible development and implementation in specific target groups	At least 2 scientific publications by M48 regarding integrating ethics for each target group.

Novel formal models to better understand the adaptive benefits and costs of higher and lower levels of emotion regulation, depending on individual characteristics and environmental context	1 scientific publication on formal models by M84. At least 2 scientific publications on the update based on insights from the PARs, RCT and the police-youth interactions by M96
Novel interdisciplinary theory on optimal emotion regulation	1 theoretical paper by M48
A co-designed roadmap towards future implementation of emotion regulation training in police and youth	Implemented from M72 onwards, evaluated through the achieved societal outcomes
Knowledge clips, podcasts, lectures etc. on emotion regulation in professionals and youth at risk for knowledge transfer of the results of CONTEXT to stakeholders, policy makers and the general public.	At least 4 knowledge clips for youth, (forensic) youth workers, police and police trainers. Annual symposia for stakeholders with lectures and discussions regarding CONTEXT results. Public lectures in local theaters and with organizations like Radboud Reflects. Participation in knowledge conferences (e.g. De Kennis van NU: organized by the Ministry of safety and justice).

Outcome	Indicator
The international scientific community builds on the models and theories from CONTEXT regarding individual differences in emotion regulation under stress	0-2 years after the project, publications with CONTEXT results within the top 80% of most viewed / downloaded / cited papers within their respective outputs
The international scientific community builds on the revolutionary dual-loop biofeedback intervention developed by CONTEXT	0-2 years after the project, publications with CONTEXT results within the top 80% of most viewed / downloaded / cited papers within their respective outputs
Police Academy integrates CONTEXT training in the standard curriculum of OVDP (Officier van Dienst Politie)	0-5 years after the project, OVDP receive this training; 200 officers are trained per year
Police Academy integrates CONTEXT training in the curriculum for the bachelor police	0-5 years after the project, bachelor students receive this training; 250 recruits trained per year
Police Academy implements CONTEXT training in the basic national police training	3-8 years after the project, basic recruits receive this training; 3000 recruits trained per year
Police Academy implements CONTEXT (booster) training to (re)train active police	3-8 years after the project, >1000 active police are (re)trained each year
Bureau Halt, Levvel, iHUB, Fivoor, Yope, and similar (forensic) youth services implement CONTEXT training as part of their program	0-3 years after the project, cooperation partners Halt, Levvel, iHUB, Fivoor and Yope provide CONTEXT training to >100 youth each year
Police and youth at risk become aware of mechanisms of emotion regulation in stressful situations, both regarding themselves and for the “opposing” group	6-8 years after the project start, approx. 100 police and youth interact through the exposition “human work” at the Police Academy Apeldoorn
Stakeholders developing policy have insight in and are aware of the importance of emotion regulation training for professionals and youth at risk	0-3 years after the project, at least 2 relevant cooperation partners (e.g., Emmen, KMAR, MinDef, Fyment, PZP, iHUB, Levvel) have integrated emotion regulation training in their policies and trainings