The mathematics resilience approach to mathematics anxiety: Is this supported by self-determination theory?

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One approach to the problem of mathematics anxiety, that of developing mathematical resilience (MR) focuses on enabling learners to remain in the growth zone, where learners experience challenge and manage any threat. This approach, involving the use of three tools (the growth zone model, hand model of the brain and the relaxation response) has been successful in small-scale studies. We show here how the theory and practice of MR can be grounded in self-determination theory (SDT) (Deci & Ryan, 2000), with connections to SDT concepts of: autonomous motivation; the basic psychological needs of autonomy, competence and relatedness; and emotion regulation. Extensive research evidence has indicated that the satisfaction of basic psychological needs leads to well-being and that frustration of these needs leads to ill-being, indicating the potential of SDT to support research and practice in the specific area of ill-being known as mathematics anxiety.

Keywords: mathematics anxiety; mathematics resilience; self-determination theory

Mathematics anxiety and mathematics resilience

The international PISA studies of 15-year-olds reported that 30% experience helplessness and emotional stress when working on mathematics problems (OECD, 2013), affecting achievement, behaviour, and well-being. Teachers, parents, and support staff may perceive disengagement/avoidance/acting out rather than anxiety; learners may say "I can't do maths", "I'm stupid", but may feel anxious, frightened, even panicked. Teachers may become protective and avoid setting challenges or assume not all can learn mathematics (Johnston-Wilder & Moreton, 2018). In the UK, there is intense pressure on teachers for results – is there any space for addressing mathematics anxiety?

One approach is that of developing mathematical resilience (MR), defined as "maintaining self-efficacy in the face of personal or social threat to mathematical well-being" (Johnston-Wilder & Lee, 2019, p.3). The focus of this approach is well illustrated with reference to one of the main tools used: the Growth Zone Model (GZM) shown in figure 1 below. Learners can identify themselves as being in one of three emotional zones at any time. Cruising in the comfort zone, where learners feel safe, can build self-confidence & provide opportunities for practice & automaticity. New learning happens in the growth zone, where learners feel challenged – it should be safe to get stuck, make mistakes, require support & find activity difficult and tiring. The panic zone is where what is being asked is not within the learner's reach yet, even with support, and the learner experiences a state of threat. Stress increases and little or no useful learning takes place. The focus of MR research and practice has been on enabling learners to stay in/return to the growth zone, where the most effective learning happens.

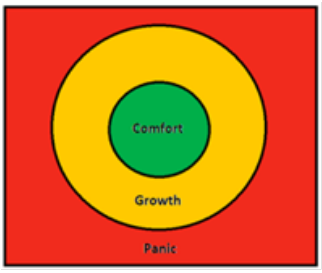

Figure 1 The Growth Zone Model

Mathematical resilience proposes some relatively simple tools: the GZM, hand model of the brain, and relaxation response (Johnston-Wilder, 2018). These are relatively straightforward to introduce. Use of these three tools has led to better behaviour, improved attainment and increased willingness to engage with challenge (see for example, Johnston-Wilder & Moreton, 2018). However, existing studies are small-scale, and the theoretical grounding of MR could be described as a bricolage. We argue that it is possible to give MR a more coherent grounding in theory in order to develop a common language to use among practitioners, facilitate larger-scale research and further the mainstreaming of MR ideas. We propose that self-determination theory (Deci & Ryan, 2000; Ryan & Deci, 2017) can provide some additional grounding through integrating many of the existing ideas and practices of MR and may also be a source of new insights.

Self-determination theory (SDT)

Ryan (clinical psychologist) and Deci (experimental psychologist) have been working together since the 1970s, with a common interest in human growth and well-being. Two aspects of SDT (motivation, and the basic psychological needs of autonomy, competence and relatedness) were established very early on (Deci & Ryan, 1985). A third aspect (emotion regulation) is more recent (Roth, Vansteenkiste, & Ryan, 2019). There have been hundreds of research findings concerning SDT across different contexts, cultures, and age ranges, including findings in mathematics education (Durmaz & Akkus, 2016; Lazarides & Rubach, 2017; Ng, Liu, & Wang, 2016).

The basic assumption of SDT is that people are naturally proactive rather than passive or reactive, aspire to shape and optimize their life conditions, with tendencies to develop toward more coherent and unified functioning (Vansteenkiste & Ryan, 2013) but recognising that social, economic, and cultural conditions may either support or obstruct these innate growth tendencies (Ryan & Niemec, 2009). The implication for MR is that the Growth Zone is a natural state, but that learners may be either supported in or obstructed from being in this state.

Motivation in SDT

Amotivation is the state of no motivation. Actions may be either actively or passively avoided. A mathematics student might stay away from class or shut down when in class, and no learning occurs. In contrast, *intrinsic motivation* is about active engagement with the environment – playing, exploring, investigating, etc. without external pressure or reward – leading to significant learning. *Extrinsic motivation* means engagement with behaviours because of their instrumental value.

Extrinsic motivation can be divided into two major categories: *controlled regulation*, behaviour engaged in because of external threat, to avoid guilt, or to gain approval, and *identified/integrated regulation*, behaviour engaged in because it is seen as valuable – in itself, or in pursuit of personal goals and values (Ryan and Deci, 2017). A person acting under controlled regulation might attempt to do maths for fear of punishment or disapproval; a person acting under integrated regulation might persevere with mathematics because they recognize the value of mathematics in their daily life or for future career plans. Controlled regulation can lead to less effective learning, and to the development of anxiety, while integrated regulation, choosing to engage in learning even though it is not intrinsically enjoyable, involves persistence and perseverance (recognized as important in MR) and can lead to effective learning (Williams, 2014).

Autonomous motivation is intrinsic motivation plus integrated regulation. Autonomous motivation is related to higher well-being, better performance, greater persistence, and enhanced behaviour change (Ryan & Deci, 2017; Durmaz & Akkus, 2016). This is the motivation we need for learners to be able to remain in the growth zone – to value the mathematics, even though it is not always fun, and also to value the ability to persist and persevere in learning, recruiting support as needed.

Basic psychological needs in SDT

Basic psychological needs are what is required for healthy development and wellness. "To be a basic need, there must be observable and meaningful positive consequences for health and thriving stemming from its satisfaction and significant harms stemming from its deprivation or frustration" (Ryan & Deci, 2017, p.82). To be basic, psychological needs also must be demonstrated to be essential across developmental periods and cultural contexts.

Ryan and Deci identify three fundamental psychological needs, the first being autonomy. When a person's need for autonomy is met, the person owns their actions and regulates their own behaviour rather than feeling controlled by pressure (Ryan & Deci, 2017). Autonomy is facilitated by and also facilitates engaging in autonomously motivated activities. If this need is frustrated, the person experiences feelings of pressure and internal conflict. MR requires that learners be in environments that allow and encourage autonomy; learners need to be able to make choices about learning zone, strategies for learning, asking for support, emotion regulation.

The second basic psychological need is competence, which means being effective in interactions with the environment, and having means for the exercise, expansion, and expression of capacities (Ryan & Deci, 2017). This need is unmet when individuals are prevented from developing skills or understanding, and if frustrated involves feelings of failure and inadequacy. We see two different competences in learners of mathematics: competence with familiar maths (comfort zone), and competence in the processes of learning mathematics – having strategies for learning, and strategies to stay in the growth zone. We have referred elsewhere (e.g. Johnston-Wilder, Lee, Brindley, & Garton, 2015; Findon & Johnston-Wilder, 2017; Cousins, Brindley, Baker, & Johnston-Wilder, 2019) to the importance of a growth mindset (Dweck, 2006), self-efficacy (Bandura, 1997), perseverance and persistence (Williams, 2014), and awareness of strategies when stuck (Mason, Burton, & Stacey, 2010); these can be linked together as components of competence as a learner of mathematics.

Relatedness is the third basic psychological need. This involves experiencing others as responsive, sensitive, and caring, and in turn being able to be responsive, sensitive, and caring to others. Relatedness involves feeling connected and involved with others and having a sense of belonging (Ryan & Deci, 2017). If this need is not met, individuals experience feelings of loneliness and abandonment, not fitting in, isolation, feeling stupid in relation to others. Lack of relatedness can be a major source of maths anxiety, and MR has consistently stressed the crucial nature of acceptance and support in a community of learners of maths. The GZM as a tool very much aids the communication needed to begin to establish the type of support that a learner may need, particularly when red zone panic may otherwise be invisible to others. SDT gives this added weight; needing support and connection can be seen as a sign of weakness, but SDT stresses that this is a basic human need, and MR a core component of resilience.

There is extensive research evidence that shows that meeting of basic psychological needs leads to well-being and thwarting leads to dysfunction (Ryan & Deci, 2017). A particular example is Durmaz and Akkus (2016) who found that with 10th grade students, satisfaction of the three SDT basic psychological needs was associated with lower maths anxiety.

Emotion regulation in SDT

The focus of much research in emotion regulation is on ways to actively defuse strong negative emotions and promote more positive emotions. In contrast, SDT sees emotions as important sources of information; awareness of these (akin to mindfulness) and exploration of their significance allow for greater autonomous regulation of behaviour (Roth et al., 2019). MR focuses on being aware of emotions, asking learners to identify their feelings and what these indicate regarding their current learning zone, enabling them to make choices about future actions.

Dysregulation refers to emotions being experienced as overwhelming and/or disorganizing, and impossible to manage. Emotions interfere with effective functioning and the person experiences little choice in behaviour or emotional expression, e.g. “When I’m afraid or feel anxious, I can’t concentrate on other things I have to do.” Dysregulation is about being in the panic or danger zone e.g. “…crying in front of the whole class as the teacher said he couldn’t understand why I didn’t get it.” (pilot MR course, June 2019).

Controlled emotion regulation (CER) refers to diminishing negative emotions through avoidance of the emotional experience, distancing from the emotions, suppression of behavioural expression, or superficial reappraisal (e.g. “it’s not that bad”). CER is due to controlled rather than autonomous motivation, e.g. “When I feel sad, I almost always hide it, so others won’t notice it.” Interesting examples of CER are given in Chronaki and Kollosche (2019), describing Anja, a 15-year-old student who copes with feeling humiliated in mathematics classes by refusing mathematics, saying that it has no value.

Integrated emotion regulation (IER) involves a receptive awareness of feelings together with active interest in emotional experiences and their meaning, with the aim of coordinating emotional experiences with needs, values, aspirations and situational circumstances. The response might then involve distancing or reappraisal – but as autonomously motivated strategies, e.g. “Exploring my fears can help me understand important things about myself.” A stereotypical example using the GZM might go as follows: “I’m feeling stupid and panicky - red zone! Time to stop the maths and

trigger the relaxation response." The difference between this and a response involving CER is that the learner is aware of the way in which they are responding, understands that this is to perceived threat, and is actively choosing a response that will enable them to deal with the threat more productively rather than closing down and avoiding the maths. We have referred to this as self-safeguarding. Another example is the way in which the GZM enables learners to differentiate between challenge and threat, which involve similar physiological responses.

In a series of experiments (Roth et al., 2019), prior to seeing a frightening movie clip, participants were told to either "take an active interest in their feelings" (IER) or given instructions related to CER: "do their best not to show their feelings" or "try to adopt a detached and unemotional attitude". The participants given the IER instruction showed less fear and had better cognitive recall on second viewing of the clip. A possible implication is that IER, resulting in less fear and greater recall can be relatively easily introduced and can "immunize" against future adverse experiences. This gives credence to the MR tools (GZM, hand model of brain, relaxation response), which are a means to introduce IER. Even though such tools appear simple, they can be effective in "immunizing" learners against maths anxiety.

Conclusion

A large number of resonances have been identified between SDT and MR, and as such SDT adds weight to MR in both theory and practice. However, we have a number of concerns with developing our use of SDT:

1. Despite ideas similar to that of the Growth Zone Model appearing in a number of fields, we have not been able to locate any SDT work that specifically connects with this model. However, SDT emotion regulation is quite recent, and it might be that such work is yet to develop.
2. We consider "meaning" and "safety" as basic psychological needs – and SDT is adamant that these are not, only being identified when other needs are thwarted.
3. We are not convinced that "relatedness" is taken sufficiently seriously; we have not yet found SDT work that considers the specifics of people learning in communities.

However, SDT research in education is highly significant in that it indicates the harm that need-thwarting practices, in particular high-stakes testing, cause to learner well-being. SDT thus identifies mathematics anxiety as a dysfunction resulting from the thwarting of basic needs and supports the work of MR in arguing for policies and practices that support learner well-being in mathematics classrooms.

References

Bandura, A. (1997). *Self-efficacy: the exercise of control.* New York, NY: W H Freeman and Company.

Chronaki, A., & Kollosche, D. (2019). Refusing mathematics: a discourse theory approach on the politics of identity work, *ZDM*, 51, 457–468

Cousins, S., Brindley, J., Baker, J., & Johnston-Wilder, S. (2019). Stories of mathematical resilience: how some adult learners overcame affective barriers. *Widening Participation and Lifelong Learning, 21*(1), 46–70.

Deci, E., & Ryan, R. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.

Deci, E., & Ryan, R. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, 11, 227–268.

Durmaz, M., & Akkus, R. (2016). Mathematics Anxiety, Motivation and The Basic Psychological Needs from the Perspective of Self-Determination Theory. *Education and Science*, 41(183), 111-127.

Dweck, C. S. (2006). *Mindset: The New Psychology of Success.* New York: Ballantine Books.

Findon, M. A., & Johnston-Wilder, S. (2017). Addressing the low skill levels of university undergraduates in the United Kingdom. *Warwick Journal of Education Transforming Teaching*, 1, 36–54.

Johnston-Wilder, S. (2018, March 2). Improving communication, engagement and resilience in STEM classrooms in South Africa: Introducing the blog [Blog post]. Retrieved from https://blogs.warwick.ac.uk/icers/entry/introducing_the_blog/

Johnston-Wilder, Sue and Lee, Clare (2019). How can we address mathematics anxiety more effectively as a community? In: *15th International Conference of The Mathematics Education for the Future Project Theory and Practice.* Retrieved from http://oro.open.ac.uk/59217/3/59217.pdf

Johnston-Wilder, S., Lee, C., Brindley, J., & Garton, E., (2015). Developing mathematical resilience in school-students who have experienced repeated failure. In *ICER2015 Proceedings* (pp. 6358- 6367). Seville, Spain: IATED.

Johnston-Wilder, S., & Moreton, J. (2018). Developing mathematical-resilience-promoting practices in teachers. In *ICERI2018 Proceedings* (pp. 8228-8237). Seville, Spain: IATED.

Lazarides, R., & Rubach, C. (2017). Instructional characteristics in mathematics classrooms: relationships to achievement goal orientation and student engagement. *Mathematics Education Research Journal, 29,* 201–217.

Lee, C., & Johnston-Wilder, S. (2017). The construct mathematical resilience. In U. Xolocotzin Eligio (Ed.), *Understanding emotions in mathematical thinking and learning* (pp. 269-291). London: Academic Press.

Mason, J., Burton, L., & Stacey, K. (2010). *Thinking Mathematically.* Harlow: Pearson.

Ng, B., Liu, W., & Wang, J. (2016). Student Motivation and Learning in Mathematics and Science: A Cluster Analysis. *International Journal of Science and Mathematics Education, 14,* 1359–1376.

OECD (2013). *PISA 2012 Results: Ready to learn—Students' engagement, drive and self-beliefs (Volume III).* Paris: OECD.

Roth, G., Vansteenkiste, M., & Ryan, R. (2019) Integrative emotion regulation: Process and development from a self-determination theory perspective, *Development and Psychopathology, 31*, 945–956.

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness.* New York: Guilford Press.

Ryan, R., & Niemec, C., (2009). Self-determination theory in schools of education: Can an empirically supported framework also be critical and liberating? *Theory and Research in Education, 7*(2), 263–272.

Vansteenkiste, M., & Ryan, R. M. (2013). On psychological growth and vulnerability: Basic psychological need satisfaction and need frustration as a unifying principle. *Journal of Psychotherapy Integration, 23*, 263–280.

Williams, G. (2014). Optimistic problem-solving activity: Enacting confidence, persistence, and perseverance. *ZDM, 46*(3), 407-422.