Hölzel et al. (mindfulness and brain scans)

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> Hölzel, B. K., Carmody, J., Vangel, M., Congleton, C., Yerramsetti, S. M., Gard, T., & Lazar, S. W. (2011). Mindfulness practice leads to increases in regional brain gray matter density. *Psychiatry research: neuroimaging*, *191*(1), 36-43.

Psychology Being Investigated

The Hölzel et al. (2011) study, which investigated the effects of mindfulness on the brain, focuses on a few key psychological concepts.

- **Mindfulness Meditation:** Mindfulness meditation is a type of mental training that can change the brain through repeated practice. It aims to improve mental health and cognitive function through focused, non-judgmental awareness of the present moment.
- **Neuroplasticity:** The study is based on the concept of neuroplasticity, the brain's ability to change its structure by forming new neural connections throughout life. Hölzel et al. (2011) hypothesized that mindfulness meditation could cause structural changes in the brain.
- **Stress Reduction and Psychological Well-Being:** The study explores how mindfulness-based interventions, such as Mindfulness-Based Stress Reduction (MBSR), reduce stress and improve overall psychological health. The theory behind this is that mindfulness can change the way individuals relate to stressful events and thereby reduce their psychological impact.
- **Brain Areas Associated with Mindfulness Practices:** The study focuses on specific brain regions, such as the hippocampus, PCC, TPJ, and cerebellum, because of their known roles in memory, learning, emotional regulation, and self-referential processing. The changes observed in these areas after mindfulness practice may explain the psychological benefits of mindfulness.

Background

Prior research has shown that mindfulness meditation can reduce stress, anxiety, and depression, while also improving attention and emotional regulation.

These benefits may be due to changes in **gray matter concentration**, which is the amount of brain tissue responsible for processing information.

Neuroplasticity, the brain's ability to change and adapt, is a key concept in understanding these potential changes. The study aimed to provide **empirical evidence** for the effects of an 8-week Mindfulness-Based Stress Reduction (MBSR) course on gray matter concentration in the brain.

Previous studies using **cross-sectional designs** provided some evidence of structural brain differences between meditators and non-meditators.

Hölzel et al. (2011) used a **longitudinal design** to track changes in the same group of participants over time, allowing them to observe how mindfulness practices might directly influence brain structure.

This approach built on earlier research that suggested the **hippocampus**, a brain region associated with memory and learning, becomes more active during meditation.

Aims

- Tto investigate whether practice of 8-week Mindfulness Based Stress Reduction (MBSR) programme results in increase in grey matter in the hippocampus and insula regions of the brain.
- The study also sought to identify any other brain regions impacted by the MBSR program.

Method

Sample

Participants were recruited from four Mindfulness-Based Stress Reduction (MBSR) courses held at a mindfulness center in New England, USA.

The researchers studied a sample of 33 participants. Two participants who experienced discomfort in the MRI machine withdrew from the study, leaving a final sample of 31 participants.

- The experimental group consisted of 16 participants (6 males, 10 females) with an average age of 38.
- The control group consisted of 17 participants (11 males, 6 females) with an average age of 39.

All participants were either self-referred or referred by a physician due to stress-related reasons.

All participants were right-handed, healthy adults between the ages of 25 and 55, and not taking regular medication. They also had limited experience with meditation.

Individuals with metallic implants or claustrophobia were excluded to avoid discomfort or harm from the MRI scanner.

Because the participants were enrolled in the MBSR courses, the sampling technique could have been either **volunteer** or **opportunity**.

Experimental design

Hölzel et al. (2011) used an **experimental research method** with a **longitudinal design**.

The study also had elements of a **mixed design**, as it incorporated aspects of both **repeated measures** and **independent measures** designs.

Repeated measures were used for comparing brain scans and mindfulness scores within the same participants before and after the MBSR program. Independent measures were employed for comparing the MBSR group to a control group that did not participate in the program

In addition to the experimental design, the researchers also looked at **correlations** between the time participants spent practicing mindfulness and the increases in gray matter concentration.

Variables

The study focused on manipulating an independent variable and measuring its effects on several key dependent variables:

- **Independent Variable (IV):** The primary independent variable was whether participants were assigned to the experimental group, receiving Mindfulness-Based Stress Reduction (MBSR) training, or the control group, who did not receive training during the study period. The time of data collection (before and after the intervention) was also considered an independent variable.
    - **Experimental Group:** The experimental group, who underwent the MBSR program, comprised 16 participants (6 males and 10 females) with an average age of 38 years.
    - **Control Group:** The control group consisted of 17 participants (11 males and 6 females) with an average age of 39 years. They did not partake in the MBSR program during the study period but were placed on a waiting list to receive the training later.
- **Dependent Variables (DVs):** The researchers measured several dependent variables. The primary dependent variables were:
    - **Gray matter concentration**: This was operationalised using voxel-based morphometry (VBM) analysis of the hippocampus, insula and other regions of the brain.
    - **Mindfulness**: This was operationalised using the Five Facets of Mindfulness Questionnaire (FFMQ), which evaluates five distinct aspects of mindfulness: observing, describing, acting with awareness, non-judging, and non-reactivity. Participants had to rate, on a scale from '1' meaning 'never or rarely true' to '5' meaning 'very often or always true', how they were faring on five aspects of mindfulness on this questionnaire.'

Procedure

The study followed a structured procedure, outlined below:

1. **Baseline Data Collection:** Two weeks before the start of the MBSR program, all participants underwent an MRI scan and completed the Five Facet Mindfulness Questionnaire (FFMQ).
    - The FFMQ measures five key aspects of mindfulness: observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience.
    - Magnetic Resonance Imaging (MRI) scans were used to measure gray matter concentration in various brain regions.

2. **MBSR Program:** The experimental group participated in an eight-week Mindfulness-Based Stress Reduction (MBSR) program, which included:
    - **Group Meetings**: Participants engage in weekly group meetings lasting 2.5 hours each. Formal training in mindfulness exercises like body scan, mindful yoga, and sitting meditation.
    - **One full-day session:** In addition to the weekly meetings, a full-day session (6.5 hours) dedicated to these practices is held during the sixth week of the program.
    - **Daily Home Practice**: Participants receive audio recordings of 45-minute guided mindfulness exercises (body scan, yoga, and sitting meditation) and are encouraged to practice daily.
3. **Control Group Activities:** The control group did not participate in the MBSR program during the study period but were on a waiting list to participate later. They underwent the same MRI scanning and FFMQ procedures as the MBSR group.
4. **Post-Intervention Data Collection:** Two weeks after the final MBSR session, the experimental group again underwent MRI scanning and completed the FFMQ.
5. **Data Analysis:**
    - Voxel-based morphometry (VBM) was used to analyze MRI data to measure changes in gray matter concentration, specifically in the hippocampus, insula, and the whole brain.
    - FFMQ scores were analyzed to assess changes in mindfulness facets.
    - Daily diaries were used to track the amount of time spent on mindfulness exercises.

This comprehensive procedure allowed the researchers to investigate the effects of MBSR on brain structure while controlling for potential confounding variables and ensuring ethical treatment of participants.

Results

- **Increased Gray Matter in the Left Hippocampus:** The study found a statistically significant increase in gray matter concentration in the left hippocampus of the MBSR group compared to the control group.
    - The left hippocampus is associated with learning and memory and plays a role in emotion regulation.
    - There was no strong connection between the amount of time participants spent on mindfulness exercises and the observed increases in gray matter concentration.

- **Increases in Other Brain Regions:** Significant increases in gray matter concentration were also observed in other areas of the brain:
    - **Posterior cingulate cortex (PCC):** This area is involved in various functions, including processing emotions, understanding perspectives, and self-reflection.
    - **Left temporo-parietal junction (TPJ):** This region plays a role in social cognition, empathy, and understanding the mental states of other.
    - **Cerebellum:** Traditionally associated with motor control, the cerebellum also contributes to attention, language processing, and emotion regulation.
- **No Changes in the Insula:** The study did not find significant changes in gray matter concentration in the insula, a region involved in interoceptive awarenes (the awareness of internal bodily sensations). The researchers suggest that this may be because eight weeks is not enough time to induce changes in this brain region, and longer training periods might be required.
- **Control Group Analysis:** The control group showed a decrease in gray matter concentration in the posterior cingulate cortex (PCC).
- **Five Facet Mindfulness Questionnaire (FFMQ)**: Participants in the MBSR group showed significant improvement in three of the five mindfulness facets: acting with awareness, observing, and non-judging.

Conclusion

- **Mindfulness practice can lead to structural changes in the brain**: The study found a significant increase in gray matter concentration in specific brain regions of the participants who completed the MBSR program compared to the control group. This suggests that the MBSR program, and not simply the passage of time, was responsible for the observed changes.
- **These changes are linked to improved mental functioning**: The brain regions that showed increased gray matter concentration are associated with learning and memory processes, emotion regulation, self-referential processing, and perspective taking. This implies that MBSR may enhance mental well-being by positively impacting these functions.
- **MBSR improves mindfulness**: The study also observed significant improvements in three aspects of mindfulness measured by the Five Facet Mindfulness Questionnaire (FFMQ) in the MBSR group. These aspects included acting with awareness, observing, and non-judging. This suggests that MBSR effectively cultivates specific mindfulness skills.

- **The amount of practice may not be the sole factor**: Interestingly, the researchers did not find a direct correlation between the amount of time participants dedicated to mindfulness exercises and the observed increases in gray matter concentration or mindfulness facets. This suggests that factors beyond the sheer quantity of practice, such as the program structure, expert guidance, and group support, may also contribute to MBSR's effectiveness.
- **Further research on the insula is needed**: The study did not find significant changes in the insula, a brain region involved in interoceptive awareness and empathy. The researchers suggested that changes in this region may require longer than 8 weeks of practice.

Strengths

MRI Brain Scans:

Employing MRI brain scans as a research tool offers a significant strength as it provides objective and quantifiable data about brain structure and function.

This approach goes beyond subjective self-reports and allows for a more direct assessment of the neurological changes associated with mindfulness practices.

This strength enhances the study's **internal validity** by providing stronger evidence for a causal link between mindfulness and brain changes.

Use of Voxel-Based Morphometry (VBM):

The researchers utilized VBM to measure changes in gray matter concentration throughout the brain. VBM is a well-established neuroimaging technique that provides a reliable and objective measure of gray matter changes.

This technique involves dividing the brain into thousands of tiny three-dimensional units called voxels and comparing the density of gray matter in each voxel between different groups or time points.

By using this sophisticated technique, the researchers were able to obtain precise and quantifiable data on the structural changes in the brain associated with MBSR participation.

Use of a Standardized Mindfulness Program:

The study employed the Mindfulness-Based Stress Reduction (MBSR) program, a well-established and widely used mindfulness program with a structured curriculum and defined practices.

This standardization ensured that all participants in the MBSR group received the same intervention, enhancing the reliability of the findings and enabling replication of the study by other researchers.

The use of a standardized program also increases the external validity of the findings, making them more generalizable to other settings where the MBSR program is implemented.

Longitudinal Design:

Longitudinal design was necessary and mindfulness has to be practiced for a fairly long duration before substantial learning can take place for the brain to show grey matter increase.

Thus, 8-week practice of MBSR programme was deemed sufficient to observe grey matter changes in the brain.

Participant Variables:

Several participant variables were carefully controlled, including:

- **Health Status:** Only physically and psychologically healthy individuals, not taking any regular medications, were included. This controlled for potential brain structure changes that might be related to illness or medication use.
- **Meditation Experience:** Individuals with significant recent meditation experience were excluded to ensure that any changes in brain structure were due to the MBSR program and not pre-existing meditation practices.
- **Handedness:** All participants were right-handed, controlling for potential brain lateralization differences that could influence the study's focus on the left hippocampus.

Ethical Considerations:

The researchers took steps to protect the well-being of the participants. They excluded individuals with metallic implants or claustrophobia to avoid potential harm from the MRI scanner.

While MRI scans are generally considered safe, they can cause discomfort due to the confined space and loud noises. The researchers provided participants with a squeeze ball to signal if they wanted to stop the procedure due to discomfort. This measure gave participants control over their experience and ensured their safety during the scans.

Participants were also allowed to withdraw from the study if they experienced discomfort during the initial scan.

Two participants withdrew from the study after the first MRI session due to discomfort, highlighting the researchers' respect for participants' right to withdraw if they felt uncomfortable.

The study offered a reduced MBSR course fee as an incentive for participation.

Additionally, all participants, including those in the control group, eventually received the MBSR training, either during the study or afterward.

This approach ensured that all participants had the opportunity to benefit from the potential positive effects of mindfulness practice.

Weaknesses

Passive Control Group:

One methodological weakness was the use of a passive control group.

Had the control group practiced some relaxation exercise like simple deep breathing for the 8-week period, it would have helped establish whether grey matter improvement was a result of MBSR practice in particular or simply due to relaxation.

Small Sample Size:

The study involved a relatively small sample size of 33 participants, with 16 in the MBSR group and 17 in the control group.

It is possible that the observed effects may not be representative of larger populations, particularly those with different demographic characteristics or those not seeking stress reduction.

Lack of Randomization:

The study did not use random assignment to allocate participants to the MBSR or control groups. Instead, participants self-selected into the groups.

This lack of random assignment increases the risk of selection bias, where pre-existing differences between the groups could account for the observed effects.

For instance, individuals who choose to enroll in an MBSR course might already possess certain personality traits or motivations that make them more likely to experience changes in gray matter concentration, regardless of the intervention.

Lack of Blinding:

The researchers who conducted the study were not blinded to the group assignment of the participants.

This lack of blinding increases the risk of experimenter bias, where the researchers' expectations or beliefs could unconsciously influence their interactions with participants, data collection, or data analysis, potentially skewing the results.

Self-Reported Data:

The study relied partly on self-reported data, particularly for assessing mindfulness skills using the Five Facet Mindfulness Questionnaire (FFMQ).

Self-reported data is subjective and can be influenced by factors like social desirability bias, where participants may respond in ways they believe are more favorable or acceptable.

The subjective nature of self-reported data can introduce inaccuracies and limit the reliability of the findings.

Potential Confounding Variables:

While the study controlled for some confounding variables, there were still potential uncontrolled factors that could have influenced the results.

- **Social Interaction:** The study did not isolate the specific effects of mindfulness meditation from the broader social aspects of the MBSR program, such as group interaction and support. The weekly group meetings could have contributed to the observed changes, making it difficult to determine the unique contribution of the meditation practices.

- **Lifestyle Differences:** The study did not account for potential differences in lifestyle factors between the MBSR and control groups, such as diet, exercise, or sleep patterns. These factors could have contributed to the observed changes in gray matter concentration, independently of the MBSR intervention.
- **Lack of standardisation**: Holzel et al. did not monitor how participants practiced the mindfulness exercises of body scan, sitting meditation and yoga in their homes. Different participants could have practiced these exercises differently, reducing standardisation of procedure and thereby the reliability of the findings.

  Limited Generalizability to Other Populations: The study's sample comprised individuals seeking stress reduction, which limits the generalizability of the findings to other populations. It is possible that the effects of MBSR may differ in individuals who are not experiencing significant stress or who have different mental health conditions.

Issues and Debates

Application to everyday life: Improved mental and physical well-being

Mindfulness-Based Stress Reduction (MBSR) can improve overall mental and physical health.

By incorporating mindfulness exercises, such as body scan, yoga, and sitting meditation, into daily routines, individuals can develop greater awareness of their thoughts, feelings, and bodily sensations.

This heightened awareness can facilitate emotional regulation, reduce reactivity to stressors, and promote a sense of calm and well-being.

Application to everyday life: Improved academic learning

One way is that children could be enrolled into the MBSR programme for healthy development of their brain areas such as the hippocampus amongst others.

The hippocampus is known to play an important role in the formation of memories so children can benefit by developing their memory, which is useful for their academics.

Application to everyday life: Workplace applications

Organizations can implement MBSR training programs for their employees to mitigate workplace stress and enhance productivity.

MBSR can help employees regulate their emotions, improve their focus, and cope more effectively with work-related challenges.

Practicing mindfulness will help them act with awareness and become better at being non-judgmental and observant, which will improve their productivity and satisfaction.

Nature versus nurture

Mindfulness is a skill that can be learned through consistent practice (**nurture**).

The study supports **nurture** because participation in the 8-week Mindfulness-Based Stress Reduction (MBSR) program led to significant increases in gray matter concentration in specific brain. Thus, grey matter increase occurred in response to learning of mindfulness.

Mindfulness training can induce physical changes in the brain structure and function based on experiences such as acting with awareness and non-reactivity to inner experience.

The study supports **nature** because changes in grey matter due to mindfulness practice indicate the underlying plasticity of the human brain. Since the brain is reponsive to learning and changes according to it, grey matter changes were found in the study.

Individual and situational explanations

Individual differences

Preference for Specific Exercises: Participants might have gravitated towards certain mindfulness exercises within the MBSR program. For instance, some individuals may have found body scan more engaging than sitting meditation or vice versa. These preferences could influence the specific brain regions that show the most significant changes.

Variation in Mindfulness Practice: While the study's design involved structured MBSR training, individuals differed in the amount of time they dedicated to mindfulness exercises outside of group sessions. Some participants engaged in home practices like body scan, yoga, and sitting meditation for longer durations than others, possibly leading to variations in the observed changes in brain structure.

Situational explanations

- **Social Interaction During Group Sessions:** Social interaction during the weekly MBSR group sessions might have contributed to the observed benefits. Simply engaging with others in a supportive setting could have positive effects on well-being, independent of the mindfulness exercises themselves.
- **Stress Reduction as a Shared Goal:** Participants in the study were either self-referred or referred by their physicians due to stress-related concerns. This shared goal of stress reduction created a common ground for participants and might have fostered a sense of collective purpose, potentially enhancing the impact of the MBSR program.

Reductionism versus holism

- **Reductionist elements:** The study isolates and measures specific brain regions, such as the hippocampus, insula, PCC, TPJ, and cerebellum, to assess changes in gray matter concentration following MBSR. This approach is inherently reductionist, as it focuses on discrete brain structures and their potential role in mediating the effects of mindfulness.
- **Holistic elements:** MBSR is a multifaceted program that incorporates various elements beyond just mindfulness meditation, such as group social interaction, stress education, and gentle stretching exercises. Observed changes in gray matter concentration might be related to the overall impact of the MBSR program rather than just the formal mindfulness practice. This recognition of the interconnectedness of various program components and their combined influence on brain structure hints at a holistic perspective.

Keep Learning

To help reinforce your understanding and prepare for potential exam questions, here are some practice questions related to this study and the A-level psychology syllabus:

1. Outline the aim of the study. [2]
2. Name two features of the sample used in the study. [2]
3. Describe two controls maintained in the study. [4]
4. Describe the sample used in the Hölzel et al. study. [3]
5. Give one example of how lack of standardisation was a weakness in this study. Holzel et al. did not monitor how participants practiced the mindfulness. [3]
6. Evaluate the Hölzel et al. study in terms of two strengths and two weaknesses. At least one of your evaluation points must be about generalizations. [10]

7. Hölzel et al. used brain scans in their study. Identify one strength and one weakness of using brain scans to investigate the effects of mindfulness. [4]
8. Explain one similarity and one difference between the study by Hölzel et al. (mindfulness and brain scans) and one other core study from the biological approach. [8]
9. Two friends, Ken and Tom, are discussing the study by Holzel et al. (mindfulness and brain scans) in terms of nature versus nurture. Ken believes this study supports nature but Tom believes this study supports nurture. Outline one reason why you think Ken is correct and one reason why you think Tom is correct. [4]
10. Abigail has noticed that Buddhist monks spend a great deal of time meditating each day. She believes that the longer a person has been a monk the higher their hippocampal grey matter concentration. State the type of hypothesis Abigail might write if she wanted to investigate this relationship further and give one reason for your choice. [3]