Hochschule für Angewandte Wissenschaften Hamburg

Fachbereich Ökotrophologie

Fasting, Restrained Eating and Congnitive Performance

- a Literature Review from 1998 to 2006

Diplomarbeit

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1 Abstract

Previous research has shown that fasting and restrained eating detrimentally affect cognitive performance. It has been hypothesized that the act of dieting is accompanied with increased preoccupying thoughts surrounding weight, body shape and eating.

This thesis aimed to summarize current findings in the field of nutrition research. This work provides studies published between 1998 and 2006 regarding the influence of fasting and restrained eating on cognitive memory and attention. In addition, it focuses on the cognitive tests applied for this research. Each reviewed study is presented with a description of the objective, experimental design, utilise cognitive tasks, and significant outcomes, followed by a summary. The studies are assigned to three chapters: studies about the effects of short-term fasting, extended fasting, and restrained eating. An overview and detailed description of the utilise cognitive tasks is given in the appendix.

The current research strengthens the previous findings of impaired cognitive memory and attention due to fasting and restrained eating. The results also support and extend the hypothesis of preoccupying cognitions as the mediating variable of these impairments. Which specific cognitive domains are affected still remains debatable.

Zusammenfassung

Führe Untersuchungen haben gezeigt, dass Fasten und gezügeltes Essen sich nachteilig auf die kognitive Leistungsfähigkeit auswirkt. Es wurde angenommen, dass Diät halten mit einer Zunahme von sogenannten vorherrschenden Gedanken über Gewicht, Körperumfang und Essen begleitet ist.

Das Ziel diese Diplomarbeit war es, die aktuellen Forschungsbefunde im Bereich der Ernährungswissenschaften zusammen zu fassen. Diese Arbeit stellt Studien zu den Auswirkungen von Fasten und gezügelten Essen auf das kognitive Gedächtnis und der kognitiven Aufmerksamkeit vor, die in dem Zeitraum von 1998 bis 2006 veröffentlicht wurden. Zudem richtet ist das Interesse auf die angewandten kognitiven Tests gerichtet. Jede dieser Studie ist aufgeführt mit der Beschreibung ihres Ziels, des Studiendesigns, den verwendeten kognitiven Aufgaben und signifikanten Ergebnissen, die jeweils mit einer Zusammenfassung endet. Die Studien sind drei Kapiteln zugewiesen: kurzzeitiges Fasten, erweitertes Fasten und gezügeltes Essen. Der Anhang beinhaltet eine Übersicht und die Beschreibung der verwendeten kognitiven Tests.

Die aktuellen Forschungsergebnisse bestätigen die Ergebnisse aus der Vergangenheit, dass Fasten und gezügeltes Essen kognitiven Funktionen Gedächtnis und Aufmerksamkeit beeinträchtigen. Ebenso bestätigen und erweitern die Ergebnisse die Hypothese, dass vorherrschende Gedanken die Ursache für diese Beeinträchtigungen sind. Welche kognitiven Bereiche im speziellen betroffen sind ist noch umstritten.

2 Introduction

Obesity is one of the major health challenges of the 21st century, stated by the World Health Organisation (2005). In Europe, the prevalence of obesity has tripled in many countries since the 1980s and the numbers of those affected continue to rise at an alarming rate, particularly among children. According to the WHO obesity is already responsible for 2-8% of health costs and 10-13% of deaths in different parts of the region. A new strategy is required for combating this rapidly growing epidemic.

Research has found that dieting is associated with an impairment of cognitive functions. Both pyhsiological and psychological mechanisms have been sought to discover leading to impaired cognition due to food deprivation. One hypothesis is that food restriction may impact the functioning of the central nervous system by reducing glucose levels in the brain. Although there has been some support for this hypothesis, the underlying physiological mechanism is not entirely clear.

Green & Rogers (1995) provide a alternative psychological explanation. They have compared the cognitive performance of women when dieting and not dieting. Their findings show that dieting women exhibit impaired cognitive function even when they are not losing weight. As an consequence of this finding, Green and Rogers suggest that thoughts about dieting, body shape and eating may place demands on limited cognitive resources, thus leaving fewer resources available for the performance of cognitive tasks. In other words, impairments of cognitive performance might be due to the act of dieting rather than due to the physiological effects of restrained eating. Various studies provide support for this hypothesis.

These cognitive impairments could have two major types of consequences: 1. The subject could experience impairment of cognitive functioning as an adverse consequence of dieting and weight loss, and thus lose motivation to diet, which would eventually affect both poor short-term and long-term success in losing weight. 2. Impairment of cognitive functioning, in particular in terms of attention and memory, could be related to impairments of self-monitoring (and eventually self-control) of food intake and physical activity, thus contributing to poor long-term success in weight loss (HAW-research-group, p.5).

In view of the prevalence of obesity in the EU-region, these conjectures have become of increasing scientific interest. The pan-European program DIOgenes (see http://www.diogenes-eu.org) aims to find new insights and new routes to prevent obesity through diet. The five-year programme involves a consortium of 29 partners across Europe. The Hamburg University of Applied Science (HAW-Hamburg) is involved in the DIOGenes project, which is one of eight Research and Technological Development Lines, and is chaired by Joachim Westenhoefer, Ph. D. As part of this research line (RTD 4 Line), one objective has been to review existing data of studies conducted between 1998 and 2006 examining the influence of fasting and restrained eating on cognitive memory and attention.

This thesis provides a delineated summary of current research in this field, focusing on cognitive performance, memory and attention, as well as on utilised cognitive tasks.

The first section of this paper describes the methodology of this research. The second section gives a short overview of the relevant terminologies and concepts. After this theoretical basis, general conditions about the studies are described, followed by a summary of the reviewed studies and the major findings. The studies included in this report are subdivided into three chapter: short-term fasting, extended fasting, and restrained eating. Finally the results are interpreted and critically evaluated and implications are provided for future research. A detailed overview and description of the tasks used in the studies is given in the appendix.

3 Methodology

The literature research was carried out via the online portal `medpilot. de´ which assesses numerous databases (see 3.1). The aim was to gather a very comprehensive collection of the specific professional articles demonstrating the effects of fasting and restrained eating on the cognitive functions memory and attention. However, the current work raises no claim to completeness.

In the process of the literature research it became evident that a subdivision in terms of evaluated fasting duration proved to be useful. Studies about short-term fasting comprise a comparison of a single meal versus no meal on cognitive performance. While studies about extended fasting demonstrate effects on cognitive performance beyond a single meal omitting. As a consequence the studies are divided into three chapters: short-term fasting, extended fasting and restrained eating.

The studies are listed in single sections and in temporal sequence. Each study starts with a crude summary, followed by a short description of the study design and cognitive tasks, the results in details and close with a detailed summary. Each chapter is summarized. In addition, for each chapter a comprehensive description of the utilised cognitive tasks of the single studies is described in tables (see appendix table 1, 2, and 3). In the last chapter (restrained eating) not only the results of the cognitive functions memory and attention are taken into consideration but also the questionnaires assessing psychological values and dieting status of studys´ participants are listed

Secondary data of the reviewed studies which were not inspected are marked with the letter „R“ (e.g. R1) and are listed separately in the section references.

In some cases terminology, findings and definitions refer to the work of the research-group of the Hamburg University of Applied Science (HAW).

3.1 Literature research

A systematic literature research was carried out including the following resources:

Interdisciplinary databases:

Medline, Medline Alert, Current Contents Medizin (CCMED), Cochrane Database of Systematic Reviews (CDSR), Hogrefe Verlag, Karger Verlag, Krause und Pachernegg Publikations-Datenbank, Springer Verlag, Thieme Verlag.

Stock of catalogues:

Catalogue of the National Library of Medicine´s (NLM), Catalogue of the german `Zentralbibliothek´ for medicine and for nutrition/environment/agriculture (ZB MED), Electronic `Zeitschriften-Bibliothek´ (EZB), Lehmanns Online.

The following keywords were requested in different combinations:

fasting, food deprivation, nutrition, cognitive performance, cognitive processing, cognition, attention, attentional bias, reaction time, stroop task, memory, working memory, dietary restraint, restrained eating, dieting, preoccuyping cognitions

In addition, reference of retrieved articles were sometimes used.

3.2 Limitations

The current work is limited to scientific publications from 1998 and 2006. In general, this work focuses on the cognitive function, memory and attention. In the section of each study `results in details´ only significant results for this work are reproduced. No main effects of tasks observed for the entire sample are taken into account, but only results which differ between the study groups. No information is given about statistical analysis used in the studies.

4 Terminological explanations

The first two sections explain the different acceptation of relevant words of the topic between german and english that concerns the topic of this work, followed by descriptions of relevant terms within cognitive psychology.

4.1 Fasting

The english word fasting has more than one meaning. In general, fasting describes the voluntary abstention, entirely or in part, and for longer or shorter periods of time, from food and drink or from food alone (especially as a religious discipline). With regard to the current work it also describes the single omitting of a meal.

4.2 Restrained eating

Restrained eating is described as a temporal relatively outlasting muster of food ingestion designated by cognitive control and oversteering of physiological hunger- and psychological appetence-signals, which aims at a lower calorie supply for the purpose of weight reduction and/or weight control (Westenhoefer & Pudel, 1989, S.150f).

`Dietary restraint´ can be taken as a synonym for restrained eating and describes the attempt to restrict food intake in order to loose weight or to prevent weight gain *(*HAW-research-group, p.3).

`Dieting´ has been described similar by Green & Rogers (1998): „Dieting can be defined as the deliberate attempt to achieve weight loss by means of the restriction of caloric intake“ (p. 1063).

The term dieting is more associated with dieting to loose weight than restrained eating.

4.3 Obesity

Obesity is the accumulation of fat. The most common method of measuring overweight and obesity in adults is the calculation of a persons` body mass index (BMI): a person’s weight in kg divided by height in metres^2. Persons with a BMI between 25 and 30 are considered overweight, persons with a BMI above 30 are considered obese.

4.4 Cognition

Cognition is a general term and describes the operation of the mental processes involved in synthesizing information to acquiring, storing, retrieving and manipulating. For example, perception, attention, memory, and reasoning. Cognitive function underpins all of our everyday activities.

4.5 Working memory

Working memory is a theoretical framework within cognitive psychology that refers to the structures and processes used for temporarily storing and manipulating information. There have been numerous models proposed regarding how working memory functions, both anatomically and cognitively. One of those, that has received the distinct notice of wide acceptance is Baddeley´s model of working memory. (www.encyclopedia.thefreedictionary). Nevertheless, at a practical level, working memory contains several different components, for which different "capacities" are available. Thus, the capacity for numbers may well be quite different from the capacity for words, and both from the capacity for visual images.

4.6 The Baddeley and Hitch model of working memory

Green et al., (2003) have stated: „Working memory (as concepualised by Baddely and Hitch (1974), (R2) can be regarded as the fundamental cognitive processing system, which serves to remember the moment-to-moment rules of action and allocate processing capacity to other, ongoing cognitive activities“ (p. 146).

In the framework of Baddeley and Hitch working memory is defined „as a system involved in the temporary storage and manipulation of information that comprises the central executive, and two subsidiary systems: the phonological loop, and the visuo-spatial sketchpad which are involved in the processing and brief storage of verbal and visuo-spatial material, respectively (Baddeley, 1986; R3). The central executive is responsible for the focusing and switching of attention, monitoring of strategies, and the integration of information from various sources (Baddeley, 1996; R4). The central executive is also responsible for supervising and allocating attentional resources to the subsidiary system“ (Vreugdenburg et al., 2003, p. 292).

The phonological loop, which is responsible for the temporary storage and processing of verbal information, comprises two sub-components: the phonological store and the articulatory control process. „The phonological store is responsible for holding speech-based material for a short period of approximately two seconds, ... The articulatory control process converts speech-based information into a phonological code that can be stored in the phonological store and refreshes and maintains these codes by means of sub-vocal rehearsal“ (Vreugdenburg et al., 2003, p. 292). A illustrative specification is quoted from the online encyclopedia wikipedia. org: „The phonological store acts as an 'inner ear', remembering speech sounds in their temporal order, whilst the articulatory process acts as an 'inner voice' and repeats the series of words (or other speech elements) on a loop to prevent them from decay.“ The other subsidiary system, the visuo-spatial sketchpad, „stores visual and spatial information. It can be used, for example, for constructing and manipulating visual images, and for the representation of mental maps. The sketch pad can be further broken down into a visual subsystem (dealing with, for instance, shape, colour, and texture), and a spatial subsystem (dealing with location)“ (http://encyclopedia.thefreedictionary.com).

5 General conditions of the studies

In general, studies differ in terms of design, measures of cognitive performance, utilises cognitive tasks and study limitations. In the following this topic is just outlined briefly.

Besides the difference of study design (e.g. numbers and age of participants, study procedure, and pursued objective) cognitive performance is measured for different cognitive domains, as well as with different cognitive tasks. Hence, a comparison of the study results is widely restricted.

In choosing a task, much depends on wether a short-term (immediate) effect of nutrition is expected or wether a long-term (chronic) effect of nutrition is being examined. Studies about long-term effects are still scarcely conducted. In previous studies (before 1998), some of the more frequently tasks used are Bakan test (assess attention), Simple or Choice Reaction Time (decision time and movement time), Immediate recall and Word recognition (Working memory/short-term memory), Digit span (Immediate memory), Pursuit rotor and Tapping task (Psycho-motor performance/tracking ability (FUFOSE report, 1998, p. 179). Numerous tasks have been added to measure cognitive performance. See Tables.

However, differences in sensitivity of applied tests lead to inconsistent results.

Another problem of cognitive tasks is that age differences in performance can be related not only to age differences in specific age-based functions but also to age gradients in pre-experimental task-relevant knowledge or cohort effects. Therefore, whenever the focus of interest is on specific aspects of cognitive performance the materials employed must be equivalent across age groups (at some level of analysis at least).

In terms of negatively correlation between dietary restraint and academic perfomance Brunstrom et al. (2005) indicated that their „measures of dietary restraint might be operating as a proxy for differences in socio-economic background that are otherwise responsible for variation in cognitive performance“ (p.239). Further Brunstrom and colleagues explained that they were at present not aware of any data indicating that reaction time is related to socio-economic status.

A example of a different kind is stated by Benton & Parker (1998): „One problem with allowing subjects to choose wether to eat breakfast is the risk of self-selection: were the investigators simply measuring diurnal rhythms? Do people who eat breakfast remember more easily because they are more alert in the morning?“ (p. 775).

This refers to a potential pre-exisiting factor influencing cognition: the circadian rhythm which includes up and downs in humans cognitive performance. This depends on the time of day. It is described as the time-of-day (TOD) effect and suggests that what is important is the time of day you hear/see/read something, not when you try and remember it (Folkard & Monk, 1978), (http://www.memorykey.com).

Poenicke et al. (2005) noted, that study participants who underwent voluntary long-term food restriction may exhibit different consequences as study participants who underwent dieting for the first time.

Changes of nutrition habit due to study manipulations may also influence performance.

6 Studies about the effects of short-term fasting

In the following section three studies about the effects of short-term fasting on cognitive performance are presented, whereby two of these studies include several experiments; these are summarised.

In general, the studies used a procedure where participants were tested in the morning after an overnight fast, following a standardised breakfast or no dietary restriction was implemented. Most studies examining short-term fasting are related to a rise in blood glucose levels. For that the effects of a glucose-laden drink (sometimes administered as one of the breakfast condition) were examined. Not all studies showed positive effects of breakfast or glucose drink consumption on cognitive behaviour. Differences in breakfast composition may be accountable for some of the contradictory results across studies.

In the present work, these differences are not described more closely. Rather the focus is concentrated on the differences in cognitive function following fasting (respectively meal omitting) compared to having a meal (breakfast). For an overview and the description of the cognitive tasks used in the presented studies see Table 1.

6.1 Benton & Parker, 1998. Breakfast, blood glucose, and cognition. Second and third experiment.

The comparative study of this work includes three experiments, whereby only the last two experiments are considered, because they were conducted during the time concerning this work. The aim of both studies (experiment two and three) was to explore the role of blood glucose in breakfast-induced improvement of different forms of memory function, by systematic manipulation of the amount of blood glucose.

Both experiments were conducted in a research laboratory in the United Kingdom. Participants in the second experiment were 80 undergraduate women, with an average age of 22.63 years. While in the third experiment participants were 123 women and 47 men, with an average age of 22 years.

Study design and cognitive tasks

In both experiments the subjects followed their normal routine of eating or not eating breakfast before they arrived in the laboratory. By means of food tables and standard portion sizes the energy content of their reported breakfast was calculated. In a double blind procedure, the subjects randomly consumed either a glucose or placebo drink. Four groups were shaped and compared:

1) Breakfast and glucose drink, 2) Breakfast and placebo drink, 3) No-breakfast and glucose drink and 4) No-breakfast and placebo drink. Testing began 20 minutes after the drinks were served.

To assess cognitive performance in the second experiment a Brown-Petersen task was conducted. Performance in the first four trials was compared with that in the last four. The cognitive memory tasks in the third experiment comprised Word list and Wechsler Memory Scale. See Table 1.

Results in details

In experiment two, those in the placebo group who did not eat breakfast (group 4) did not significantly improve from the first four trials to the last four trials on the Brown-Petersen task. Participants who did not eat breakfast but drank the glucose drink (group 3) significantly improved between the trials. The breakfast groups showed practice effects whether they drank the glucose drink or not. Trigrams were recalled with lower accuracy by participants who did eat breakfast but drank a placebo (group 2) compared to the other three groups. For the two breakfast groups, the glucose drink was of no further benefit.

In experiment three, on the Word list, subjects who fasted and consumed the glucose drink (group 3) recalled more words than those who fasted and had taken the placebo drink (group 4). The group who ate breakfast and drank the placebo drink (group 1) recalled more words than the group who fasted and had taken the placebo (group 4). If subjects had eaten breakfast, the type of drink did not influence the number of words recalled. On the Wechlser story, subjects who had eaten breakfast recalled more words than those who fasted. The glucose drink did not influence recall of the story, regardless of whether the subjects had fasted.

Summary

The results of the two experiments of Benton & Parker (1998) revealed an improved performance on three memory tests due to breakfast consumption (by raising blood glucose) after an overnight fast, but an additional glucose drink was of no further benefit. Moreover, in those who had fasted, glucose ingestion resulted in memory performance comparable to those who had consumed breakfast (experiment 2). However, if subjects fasted, the glucose drink benefited subjects` task performance on the Word list recall and memory while counting backwards compared to a placebo drink. However, the glucose drink did not improve the ability to recall a story read loud when subjects had fasted.

The results partially confirmed previous reports that eating breakfast was associated with improved memory later in the morning. The authors pointed out, the question remains whether an increase in blood glucose associated with breakfast consumption enhances other types of cognitive functioning,

particularly aspects of memory. Benton and Parker suggest that breakfast facilitates memory irrespective of its composition. Therefore, they recommended that future studies should examine whether the nutritional composition of the morning meal influences memory to a greater or lesser extent.

Further, they take into account that it could be the case that people who usually eat breakfast remember more easily because they are more alert in the morning. The authors suggested that the raising of blood glucose after breakfast is not the only mechanism that benefits memory. They supposed that missing breakfast also appears not to uniformly affect psychologic function and recommended that the demands places on the brain and the nature of the memory test are important varibles that require further scrunity.

6.2 Wesnes et al., 2003. Breakfast reduces declines in attention and memory over the morning in schoolchildren.

The study took place in a research laboratory in the United Kingdom. It was examined how breakfast influences cognitive performance in schoolchildren. The aim was to determinate the extent to which breakfast cereals would help to prevent decline in cognitive function in school children. Participants were 15 females with an average age of 12.3 years, and 14 males with an average age of 12.1 years. The results showed that declines in attention and memory were significantly reduced after the breakfast conditions.

Study design and cognitive tasks

The study follows a randomized, four-way cross-over design (in between comparison). The participants attended the laboratory on five consecutive days (monday to friday). The first day served to familiarize the participants with the tests. Over the next four days, each participant had each of the following four breakfasts: 1) shreedies, 2) cheerios, 3) orange-flavoured (glucose-laden) drink, 4) no breakfast. The cognitive tests were administered prior to breakfast every day at 8.00 am (baseline performance). Immediately afterwards, the `breakfast´ was administered. Testing was repeated at four times till 12.00 noon. In addition, ratings of mood and alertness were administered after each test session.

A selection of the Cognitive Drug Research computerised assessment system (CDR) was used to assess attention, working memory and episodic secondary memory. The CDR is a computerised assessment system (Wesnes et al., 2000; R6) which comprises a wide range of tests of various aspects of human cognitive function. It is an automated test system.

The following tests were used: Word presentation, Immediate Word Recall, Picture Presentation, Simple Reaction Time, Digit Vigilance, Choice Reaction Time, Spatial Working Memory, Numeric Working Memory, Delayed Word Recall, Word Recognition and Picture Recognition. See Table 1.

Results in details

Two of the cognitive assessment factor scores, power of attention and quality of episodic memory, showed significant detrimental main effects and significant variations over the morning. There was a general decline in cognitive performance over time if the participants did not ate breakfast but the magnitude of this deficit was reduced by more than half at the end of the morning following consumption of breakfast cereals. The glucose drink showed no positive effects; indeed the deficits to attention were greater soon after the glucose drink than with no breakfast.

Six of the seven contributed measures gave significant effects when analysed seperately. Immediate word recall (contributes to the quality of episodic memory index) demonstrated a particularly strong effect. By midday after no breakfast, the ability to recall words decreased by 12 %, and by 27% with the glucose drink, while the decline after Cheerios was 3 %, and after Shreedies 5 %. The speed with which items could be retrieved from working and secondary memory (speed of memory) showed a general increase over the testing session, displaying that this ability improves over the morning. However, the improvements were 2 – 3 times greater if the participants had consumed a cereal or a glucose drink.

Summary

Wesnes and colleagues demonstrated that cereal breakfast has a positive effect of the cognitive function of schoolchildren, in particular towards noon. Omitting breakfast led to impairments in attention and episodic memory, and this impairment increased in magnitude over the morning. The glucose drink failed to have beneficial effects on attention or episodic memory. Indeed there was a greater initial impairment with the drink than with no drink or breakfast.

The authors recommended investigations about the extent to which different types of breakfast influence different domains of cognitive function. „In particular, the role of complex carbohydrates in helping to maintain performance over the morning should be evaluated further“(p. 331).

6.3 Mahoney et al., 2005. Effect of breakfast composition on cognitive processes in elementary schoolchildren.

Both experiments were conducted in the USA, in a test room in the school, during the 2000/2001 school year. The study compared the effects of two breakfast compositions versus no breakfast on memory and attention performance in elementary schoolchildren. A glucose drink was not included. They carried out two experiments with differently aged schoolchildren, using the same battery of cognitive tests. In the first study participants were 30 elementary school children, aged between 9 and 11 years. In the second study participants were 15 male and 15 female elementary school children, aged between 6 and 8 years.

The authors were interested in this younger age group with regard to different metabolic factors in younger children, which may affect cognitive performance more dramatically, and the amount of basic skills they learn in these years. They explained that difficulty learning these skills may lead to long-term disadvantages. The aim was to evaluate the effects of two common U.S. breakfasts foods (instant oatmeal and ready-to-eat-cereal) compared to no breakfast on children`s cognitive performance (memory & attention).

Study design and cognitive tasks

In both studies a within-participant design was used. Once a week for three weeks, children consumed one of two breakfast or no breakfast. Children fasted from 10:00 pm the night before testing. The children were sent to school the day of testing without breakfast. Three breakfast conditions were compared. 1) ready-to-eat-cereals, 2) instant oatmeal, 3) no breakfast. Across the experiment, each participant received all three breakfast conditions. The experimenter was blinded to the breakfast conditions, which were administered in a counterbalanced order. The children completed the tasks one hour after the `breakfast´.

The cognitive tasks of both studies included Map task (spatial memory), Digit Span (short-term memory), Rey Compley Figure Copy and Recall Test (visual perception), Continuous performance task (CPT) (visual attention and auditory attention), Verbal task (verbal memory). Appropriate modifications to age were made to the verbal memory and the spatial learning tasks. See Table 1.

In addition, a questionnaire addressing current dietary and sleeping patterns and medical history was completed by all parents. A mini-questionnaire, assessing mood, energy level, and hunger levels was filled out. Also a diet and opinion survey was conducted to determine among other things how often children consumed breakfast before school.

Results in details

In the first experiment measures often revealed a detrimental effect for the no breakfast condition (short-term recall on the Map task; short-term memory for girls on the Digit Span; accuracy, drawing time and accuracy over time on the Rey Com. Fig. Copy & Recall; false alarms within the auditory part on the continuous performance task) but also found no effects of breakfast conditions (long-term recall on the Map task; Digit span for boys; delayed recall and long-term memory on the Rey Com. Fig. Copy & Recall, and on the CPT) except for the false alarms within the auditory part of the CPT task.

In the second experiment participants also showed adversely effect on the Map task (short-term recall). As in experiment one, girls recalled more digits on the backward Digit span (short-term memory) after consuming breakfast than with no breakfast and boys showed no differences in either breakfast and no breakfast condition.

On the Rey Complex Figure Copy and Recall Test (visual perception) boys performed significantly worse after no breakfast than after breakfast (ready-to-eat-cereals). In contrast, girls performance was significantly better after no breakfast than after breakfast (ready-to-eat-cereals). In both cases the effect of oatmeal did not differ between either of the other two conditions. Measures of the auditory part of the CPT revealed best results after oatmeal breakfast, followed by no breakfast and finally the ready-to-eat cereals.

Summary

The results supported previous findings by demonstrating that omitting breakfast led to an impairment in school children on most measures of cognitive performance used in the study. In general, the children showed enhanced cognitive performance after breakfast, particularly on tasks requiring processing of a complex visual display. Moreover, the results suggested that the type of breakfast can also influence children`s cognitive performance on some measures, particularly spatial memory, short-term memory, visual perception and auditory attention. For example, 9 to 11 years old participants performed better on a short term memory task after consuming the oatmeal breakfast compared to when they consumed the ready-to-eat cereals or no breakfast. The 6 to 8 years old participants performed better on a short term memory task and an auditory attention task when they had oatmeal compared to ready-to-eat cereal.

But two contradictions were found in this study: younger girls performed better on the visual perception task after no breakfast compared to ready-to-eat cereal and the younger boys performed better on the visual perception task after ready-to-eat-cereal compared to no breakfast. In both

cases, the result with oatmeal breakfast did not significantly differ from either of the other two breakfast conditions.

The authors pointed out, the reason for that difference between boys and girls after breakfast consumption remains unclear. They conceived mood as a possible factor.

6.4 Summary

The studies largely demonstrate the general benefit of breakfast consumption on memory and attention. It is noteworthy that each study used different cognitive tasks to do so.

Benton & Parker (1998) compared the effects of breakfast and resulting increased blood glucose levels on cognitive function and recommended that future studies should investigate to which extent different breakfast compositions influence this functioning. Psychological functions were assumed to be possible additional factors influencing cognitive performance. The final two studies described above focused on different breakfast compositions. Mahoney et al. (2003) revealed that oatmeal consumption led to the best results for cognitive performance. Therefore, they indicated the variable digestion rate as a possible factor. Mahoney and colleagues affirm the conclusion of Benton & Parker (1998) that psychological influence (mood) could be a contributing factor affecting cognitive performance. Nevertheless, all studies reviewed recommend further investigations about the role of breakfast compositions.

In view of the insinuated psychological factors affecting cognitive function, it seems evident that future research should extend investigations about the influence of omitted meals beyond physiological-related values (glucose).

The practical value of the results summarized here lies in the importance of breakfast. Assuming that dinner is typically consumed between 6 and 8 pm, a period of approximately 10 hours generally passed before the morning meal. After such a period of fasting the importance of breakfast becomes evident with regard to the negative influence of not omitting breakfast presented here. Previous researchs suggest that the number of children skipping breakfast is on the rise. The results of a diet and opinion survey revealed that only 52% of children aged 9 - 11 years, and 64% of children aged 6- 8 years were eating breakfast on a regular basis (Mahoney et al., 2003). For parents, the implication of these results should be to encourage continuous breakfast behaviour. In particular, as Mahoney et al. (2005) note, parents might pay more attention to what they are feeding their children before school.

7 Studies about the effects of extended fasting

In the previous section the effects of an overnight fast respectively breakfast omitting compared to having a meal was examined. In the following three studies the experiments refer to the effects of extended fasting on cognitive performance beyond a single breakfast omitting. However, the investigation procedures differ conspicuosly. For an overview of the cognitive tasks used in the presented studies see Table 2.

7.1 Roky et al., 2000. Daytime Alertness, Mood, Psychomotor Performance, and Oral Temperature during Ramadan Intermitting Fasting

The study took place in a research laboratory in Morocco. The authors examined the effect of Ramadan intermittent fasting on the diurnal alertness and additionally on oral temperature and mood. The results of oral temperature and mood are not considered closer. During the month of Ramadan, Moslems abstain from drinking and eating daily between sunrise and sunset. The aim was to determine the daily distribution of alertness and body temperature during Ramadan fasting. Body temperature is assumed to present a circadian rhythm. The idea that changes in body temperature and alertness are correlated was orginated by Monk et al. (1983), (R7). Participants were ten males, aged between 20 and 28 years. The results showed that subjective altertness, oral temperature and mood were decreased during Ramadan intermittent fasting.

Study design and cognitive tasks

An in between participants comparison was conducted at three fast days and two non fast days. The non fast days were one week before Ramadan (baseline day) and the 18th days after the end of Ramadan (recovery day). The three fast days were the 6th fasting day (R6), the 15th fasting day (R15), the 28th fasting day (R28) of Ramadan. Testing time was administered at six different times of day: 9:00 am, 11:00 am, 1:00 pm , 4:00 pm, 8:00 pm and 11:00 pm. Oral temperature was measured prior to each test session and 0:00 at midnight. Prior to each session day participants slept in the laboratory and stayed in the laboratory during the session day.

The cognitive tasks included Critical Flicker Fusion (CFF) and Choice Reaction Time (CRT), whereby on the CRT only the movement reaction time values were reported. To assess subjective alertness and vigor a Visual Analogue Scale (VAS) was administered. See Table 2.

Results in details

With fasting the global alertness varied. During R6, R15, and R28 global alertness significantly decreased. An interaction between fast-day and time-of-day (TOD), (see 5., p. 13) effects during R6 and R15 was revealed. Global alertness decreased at 9:00 am and 4:00 pm during R6, R15, and R28, and increased at 11:00 pm during R15. Only for the baseline day there was a significant time effect; the highest global alertness ratings were observed at 9:00 am and at 4:00 pm and the lowest at 1:00 pm and 11:00 pm.

Movement reaction time increased significantly during the first fasting period, but no significantly time-of-day (TOD) effects were found. Global mood was impaired with fastin but did not show a time of day effet.

Oral temperature decreased during daytime and increased during nighttime. Change in oral temperature and alertness were related since they decreased concomitanly at 9:00 am and 4:00 pm.

Summary

The results showed that subjective alertness decreased during Ramadan intermitting fasting. The authors explained, that the changes of meals schedule (all meals were nocturnal) is accompanied with changes in sleep habits (e.g. sleep shortening), which may affect diurnal alertness. Further they suggested that the concomitant decrease of mood and alertness at 9:00 am and 4:00 pm may be related to the result of another studie (Shanks, 1994, R8), by which an increase in traffic accidents was observed in the afternoon during this month.

The measures of oral temperature revealed a decrease during the daytime and increased during the nighttime. These changes were partially related to alertness (at 9:00 am, 4:00 pm and 23:00 pm). This result is consistent with the idea of Monk et al., (1983) that changes in body temperature and alertness are correlated.

The authors pointed out it appears clearly that meals taken exclusively at night were responsible for the observed pattern. They are of the opinion that the findings of their study may be relevant in choosing optimal working hours of fasting Moslems.

7.2 Sünram-Lea et al., 2001. Glucose facilitation of cognitive performance in healthy young adults: examination of the influence of fast-duration, time of day and pre-consumption plasma glucose levels.

The study was conducted in in a laboratory research in the United Kingdom. Sünram-Lea and colleagues investigated, for the first time, the glucose cognitive facilitation effect under more natural testing times and with shorter duration of the previous fast. They aimed to increase the generalisability of previously observed glucose facilitation effect and to establish its ecological validity. In addition to the measures of cognitive performance blood glucose levels were analysed. Participants were 60 persons with an average age of 21 years. The results showed a significant glucose facilitation effect on long-term verbal memory performance and a glucose-related significant enhancement of long-term spatial memory performance. The daytime of glucose ingestion did not change these effects.

Study design and cognitive tasks

A between-participants 2x3 design was used to investigate the effect of a drink administration (glucose versus placebo) on memory performance under different meal conditions (fasting, breakfast, and lunch), and different fast-durations (overnight versus 2 h fast). The condition „fasting“ comprised fasting from midnight prior to testing. Testing was carried out between 9:00 and 12:00 noon. The condition „breakfast“ comprised the same overnight fast, but a standard breakfast was consumed in the morning. Testing was carried out two hours later, between 9:00 am and 12:00 noon. The condition „lunch“ comprised having a normal breakfast but no eating anything three hours before arriving in the laboratory. Participants were then given the standardised meal. Testing was carried out two hours later, between 2:00 and 5:00 pm.

The administration of the drink followed a double-blind procedure. Blood glucose was obtained before, twenty-five minutes after and forty-five minutes after the administration of the drink. Immediately after the first blood glucose reading was obtained, participants received one of the two drinks. The administration of the first cognitive test followed directly.

The cognitive tasks comprised a modified California Verbal Learning test, the Rey-Osterrieth Complex Figure Drawing, and a modified Digit Span. See Table 2.

Results in details

The California Verbal Learning Test (CVLT) comprised several subtasks:

On the Immediate free recall list (A) subtask participants who received the glucose drink performed significantly better than the placebo group. Over the course of the trials not only performance on the free recall task got better, but after the ingestion of a glucose drink a faster learning trajectory was observed. On the Immediate free recall list (B) subtask the glucose group significantly outperformed the placebo group.

On the short delay free recall subtask the glucose group remembered significantly more than the placebo group, and the breakfast condition outperformed the lunch and the fasting condition.

On the short delay cue recall subtask the glucose groups performed significantly better than the placebo groups.

On the long delay free recall subtask those who received the glucose drink performed significantly better than those with the placebo drink.

On the long delay cued recall subtask, again, performance was significantly better after the consumption of the glucose drink than after the placebo drink. Moreover, with condition breakfast participants performed better than with condition lunch.

On the long delay recognitions subtask the percentage of correct recognition showed that the performance of the glucose group was significantly better than of the placebo group. Further analysis showed that there were significant differences in the amount of discriminability, depending on drink and condition. The glucose group outperformed the placebo group and those performing the test in the morning did significantly better than those who were tested after lunch.

On the Rey-Osterrieth Complex Figure task reproduction of this task was significant better with the glucose drink than with the placebo drink.

Summary

The authors found significant fasting-related deficits in performance on the most subtests of the CVLT. The results revealed a significant glucose facilitation effect on long-term verbal memory performance, and with glucose long-term spatial memory performance was also significantly enhanced. The preceding fast-duration (overnight versus 2 h fast) did not change the effect of glucose. There was no effect of drink and time of day, (see 5) on working memory performance. The recall of visuo-spatial material and the short-term memory were not affected with fasting.

The authors demonstrated that the glucose facilitation effect is observable after a standardised meal by a two hour fast. They pointed out that this finding has consequence for everyday life, in that people are likely to have a morning and/or an afternoon glucose-containing snack or meal after a period of fasting of just a few hours` duration, and then carry out cognitively demanding tasks in their work environment (office, schools, university).

An emphasized finding of this study showed that resting blood glucose levels were generally higher after a 2 h fast compared with an overnight fast, but that resting blood glucose levels did not generally influence cognitive performance after administration of the glucose drink. Based on their results the authors expected the actual resting blood glucose level may not be critical for the effect of glucose on facilitating memory performance. They suggested that the determining fact is the actual rise in blood glucose levels following administration of the glucose drink.

Sünram-Lea and colleagues assumed that positive cognitive effects of glucose administration should also be observable under slightly higher blood glucose levels as observered in their current study. „Otherwise, the physiological basis of memory enhancement via increases in glucose levels (possibly subsequent to peripheral adrenaline actions) would be restricted, in the natural environment, to a sub-sample of humans (...) in whom baseline blood glucose levels were within a limited range at the time when the to-be-remembered episode occured“ (p. 53).

7.3 Poenicke et al., 2005. `Kognitive Veränderungen beim Fasten´.

The study took place in a research laboratory in Germany. As the only study found, Poenecke an colleagues evaluated the effects of a multi-day fast on cognitive performance. With regard to previous findings, in which extrem restriction of caloric intake has led to hormonal and metabolic changes they aimed to examine, if there are cognitive impairments after 72 hours of fasting. Participants in the fasting-group were 13 women and two men with a average age of 49.6 years, who took part in a Buchinger fasting course. Buchingers` fasting course comprise a restricted supply of caloric intake of 200 kcal a day, consumed in a liquid form. Participants in the nonfasting-group were 15 subjects, with an average age of 49.6 years.

Study design and cognitive tasks

Both groups were tested at two different days, after overnight fast (t1) and after 72 hours fast (t2). Performance of the fasting group was compared with that in the controll group (no fasting).

In t1 the Rey-Osterrieth-Figure (with a 30 min fetch), the Trail Making Test (TMT) A & B, the Frankfurter Aufmerksamkeits-Inventar (FAIR) in Form A, and the California Verbal Learning Test

was administered. In t2 the Trail Making Test A & B was administered again. The Frankfurter Aufmerksamkeits-Inventar (FAIR) was conducted in Form B and the Rey-Osterrieth-Figure was conducted without a specific fetch. Subsequent the Conditional-Associative-Learning (CAL) task was performed. See Table 2.

In addition, a scale assessing current sensitivity (mood-state) was administered.

Results in details

In the 72 hours-fasting condition (t2) the FAIR B revealed a significant enhancement in the total error number after 72 h fast in the fasting group compared to the nonfasting group.

On the Trail-Making-Test-B (TMT B) the controll group performed significantly better compared to the fasting group.

On the Conditional-Associative-Learning (CAL) task the fasting group displayed more errors than the nonfasting group.

Summary

The study demonstrated significant impairments in attention tasks and in conditional-associative learning after a 72 hour fast of a nearly complete food restriction.Verbal learning (CVLT), verbal and visuo-spatial memory (Rey-Osterrieth-Figure), and visuo-construction remained unimpaired. Besides the deficits found in cognitive performance fasting volunteers showed enhanced mood compared to the nonfasting volunteers. In contrast, the study of Roky et al., (2000), (see 7.1) found decreased mood.

It is noteworthy, that Poenicke and colleagues refered their results to the partly resembles neuropsychological deficits found in anorexia, which exceeds the general conditions of the present work.

7.4 Doniger et al., 2006. Comprehensive Computerized Assessment of Cognitive Sequelae of a Complete 12-16 Hour Fast

This study took place in a research laboratory in Israel. The aim was to assess the cognitive sequelae of complete abstention of food and drink after 12-16 hours of overnight and diurnal religious fasting by means of a computerized cognitive assessment. In addition, time-of-day (TOD) effects were evaluated. The day of the fasting manipulation was in observance of the Jewish fast of the Tenth of Tevet. The participants were 30 female and 16 mal university students, with an average age of 22.4 years. All of them were orthodox Jewish individuals. The results showed fasting-related deficits in all cognitive domains tested and pertained tasks which require perception of spatial relations.

Study design and cognitive tasks

A in-between-comparison was used to examine the effects of a fast day versus nonfast day on cognitive performance. After a complete abstention from eating and drinking beginning at midnight through evening on the day of the fasting manipulation, multiple cognitive domains were evaluated at midday and late afternoon. For comparison, participants were tested at comparable times on a different day while not fasting. The testing at different diurnal points (morning, midday, afternoon) was implemented to assess the interaction between time-of-day (TOD) and fasting effects.

The Cognitive tests were administered via computerised Mindstreams tests (Neurotrax Corporation, New York) Global Assessment Battery (formerly the Mild Impairment Battery, Dwolatzky et al., 2003; R9). See Table 2.

Results in details

In the memory domain the Non-verbal memory task showed a significant fasting-related decrement in performance. In the executive function domain, a fasting-related decrement in performance was found in the Problem Solving task.

In the attention domain significant fasting effects for response time and standard deviation of response time were observed for selected levels of the Information Processing Speed task. These effects were most dominant for the test levels of intermediate difficulty but less for the easier or harder levels. Thereby the most consistent fasting-related deficits were prolonged response times. A fasting-related decrease in accuracy was found for the medium-speed condition of the two-digit arithmetic test and the slow-speed condition of the three-digit arithmetic test.

In the motor skills domain Catch Game time-until-first-move (response time) was significantly longer on the fast-day as compared with the non-fast day. In the verbal function a significant deterioration for the naming performance was observed on the fast-day. The visual spatial domain also revealed a fasting-related decrement in performance.

Summary

The comparison of cognitive performance on a comprehensive cognitive battery of tasks in between the same individuals after 12 – 16 hours of a complete religious fast and at comparable times of day when not fasting revealed fasting-related deficits in all cognitive domains tested and were often associated with tasks requiring perception of spatial relations.

These results are consistent with those of Sünram-Lea et al. (2001), (see 7.2) who found that glucose significantly improved long-term spatial memory performance after a brief fast of two hours. Fasting-related information processing deficits were found for response time but not for accuracy on test levels of intermediate difficulty. TOD effects often led to decreased performance in the afternoon.

The authors indicated: „Although numerous outcomes showed no fasting or time-of-day effects, it remains unclear whether theses nonsignificant findings are attributable to varying and inderterminate sensitivity across outcomes or the ... resilience of the human cognitive system (...)“ (p. 812). Moreover, this was the first study which examined these effects and has used sensitive and comprehensive computerized battery. Therefore, they recommended, these findings must be replicated and extended in additional cohorts.

7.5 Summary

The findings of the studies broadly indicate that extended food deprivation detrimentally influences human cognitive function. As in the above section on studies evaluating the effects of short-term fasting on cognitive performance, the cognitive tasks used to evaluate the effects of extended fasting mostly differ between studies. Nevertheless, impairments of cognitive performance were generally found for attention (Roky et al., 2000; Pönicke et al., 2005; Doniger et al. 2006) and memory (Sünram-Lea et al., 2001; Doniger et al., 2006). Moreover, it was found that impaired cognitive functions were related to tasks requiring perceptions of spatial relations (Sünram-Lea et al., 2001; Doniger et al., 2006).

The study of Sünram-Lea et al. (2001) was the only study in term of extended fasting that examined glucose-related effects on cognitive perfomance similar to studies considered in section 6. The

authors found a glucose facilitation effect on several cognitive functions tested. In contrast, Benton & Parker (1998), who administered the glucose drink immediatley after ta meal found no further benefit (see section 6.1). Sünram-Lea and colleagues suggest that the fact that the glucose drink was administered immediately after the meal explains why these studies report no facilitative effect of glucose administration. „Taking into account that the dose-response curve of glucose upon memory performance follows an inverted U-shape, further immediate post-meal glucose administration might result in an `overload´, thus exceeding the optimun dosage“ (p.52).

However, it remains unclear to what extent glucose-related improvement is attributable to task demands, task difficulty and psychological mechanisms influenced by other factors. The hypothesis that lowering blood glucose levels by food deprivation has a negative effect on cognitive performance is, however, not entirely supported by experimental evidence.

A characteristic of the studies examining the effects of fasting consist in scarcely assessment of psychological variables. Only three studies involved the factor `mood´ in their examination. This might be due to the fact that these studies do not aim to assess the real long-term influence of fasting respectively meal omitting. With this their findings refer to the phyiological mechanisms.

Taken together, the finding that fasting-related deficits were often observed for tasks requiring perception of spatial relations and that the glucose facilitation effect is observable after a standardised meal followed by a two hours fast may have important consequences for routine tasks that require perception of spatial relations (e.g. driving) following an extended period of not eating.

8 Studies about the effects of restrained eating

Dietary restraint is an approved method in helping to prevent obesity. However, it is associated with a number of negative consequences (e.g. low self-esteem, depression, social anxiety, and developing an eating disorder). Also, dieting is associated with poorer performance with quite a number of cognitive measures.

These decrements in cognitive performance are generally thought to have a psychological rather than a physiological origin since Green & Rogers (1995) have demonstrated that performance had been poorer within the same individuals, when dieting than when not dieting. They also found increased preccupying thought among dieters and suggested that the limited capacity working memory system may be most affected by dieting.

Since then numbers of researchs have examined the hypothesis that dieting and restrained eating is associated with preoccupying cognitions, concerning dieting-related thought (e.g. weight, body shape and food). Most of the following presented studies have utilised the working memory framework of Baddeley and Hitch (1974), (see 4.7).

In terms of the psychological view of deficits in cognitive performance in dieters, self-report measures of participants assessed via questionnaires are additionally considered. It is to note that the reproduced results of the following cognitive tasks do not consider main effects (i.e. task effects which were found in the entirely sample), but only results which differ as a function of the dieting status.

For an overview and the description of the utilis tasks see Table 3.

8.1 Green & Rogers, 1998. Impairments in working memory associated with spontaneous dieting behaviour.

The study was conducted in the United Kingdom. The aim was to investigate the particular components of the working-memory system affected by dieting. Participants were 71 female students at the University of Reading, aged between 18 and 30 years. The study found poorer recall on the Phonological Loop task and slower planning time on the Tower of London task for participants who reported being currently on diet. In addition, there was a significant correlation with performance on both tasks and self-report measures of body shape concern. The data joined the hypothesis that the observed deficits in cognition among dieters results from preoccupying cognitions concerning weight and body shape.

Study design and cognitive tests

Each participant was tested individually. They completed a number of cognitive task, each of which preferentially loaded onto a different subsystem of the working memory system. Based on a number of self-report measures of eating behaviour, body shape concern, somatic sensations and recent dieting history, participants were classified as either low/medium restrained eaters (34 participants), highly restrained eaters (18 participants) or current dieters (19 participants).

The testing procedure was identical for each participant in the following order of cognitive tasks: Mental rotation task, Phonological Similarity task, and Tower of London task (TOL). See table 3.

The self-report measures comprised a modified version of the Dutch Eating Behaviour Questionnaire (DEBQ), and the Body Shape Questionnaire (BSQ). Affective state was measured via the Hospital Anxiety and Depression Scale (HADS).

Results in details

On the Mental Rotation task, the dieting subjects made significantly more correct decisions than the two groups of non-dieting subjects. On the Phonological Similarity task, the correct recall was fewer in the dieting subjects than either of the two non-dieting groups. On the Tower of London task, the dieting subjects displayed significantly longer planning time in the two most complex sets of target positions than the two non-dieting groups.

Questionnaires

On the DEBQ, dieters and non-dieting restained eaters scored significantly higher as low-to-medium restrainers. On the BSQ each group exhibited a significant different score from the other. On the HADS dieters reported a significantly lower level of anxiety than the two non-dieting groups.

Summary

The study revealed further evidence that dieting to lose weight is associated with relatively poorer cognitive processing efficiency, and that this impairment is fundamentally one of working-memory capacity. Moreover, they extended previous findings with the demonstration that current dieters performed more poorly than either non-dieting, highly restrained eaters or non-restrained eaters, on task that primarily load on the central executive and phonological loop slave systems, but not on a visuo-spatial task (Mental rotation).

Regarding the result of the Mental Rotation task (correct decisions), in which dieters performed significantly better than the non-dieters the authors explained that the finding mitigates against the

possible hypothesis that dieters` preoccupations concerning weight and body shape contain an element of visuo-spatial processing.

The result of the questionnaire (BSQ) with dieters reported less anxiety than non-dieters was suggested by Green and Rogers in that the performance differences are unrelated to disorderd mood state among dieters. Instead, they argued, this may be related to the affective state of dieters. Further the authors conceded there could be also a physiological explanation for the results. They alluded depletion of tryptophan levels (this has been examined by Green et al., (2003), see 8.3) and pointed out that the hypothesis of lowering glucose blood levels has a negative effect on cognitive processing efficiency is not entirely supported by experimental evidence. The authors concluded that their results support the hypothesis that preoccupying cognitions concerning food and body shape is the mediating variable in dieting-related deficit.

8.2 Jones & Rogers, 2002. Preoccupation, Food, and Failure: An Investigation of Cognitive Performance Deficits in Dieters.

The study took place in the United Kingdom, and was conducted in a small, quiet room. The study tested two explanations of impairments in cognitive performance of dieters. First, metabolic consequences of food deprivation is responsible for these impairments. Second, the impairments are psychological in origin (that means, preoccupation with dieting-related thoughts are responsible for cognitive deficits). Participants were 22 dieting and 17 nondieting female students and university staff, aged between 18 and 47 years. The results showed that dieters exhibit impaired performance on a memory task after food consumption (chocolate bar). Furthermore, there was a significant increase in the number of food and dieting-related thoughts in dieters. The results supported the latter explanation.

Study design and cognitive tasks

Participants were individually tested between 10:00 am and 4:00 pm. Self-reported dieting behaviour and scores on the Revised Restraint Scale (RRS) served as the basis for assigning the participants into dieters and non-dieters. After completing the cognitive tasks for the first time, participants were required to eat a chocolate bar. They were not made aware of this element before the experiment. Cognitive tasks were then administered for the second time. The cognitive performance tasks were conducted in the following order: Two Finger-Tapping task, Rapid Visual Information Processing (RVIP) task, Simple Reaction (SRT) task, and Immediate Memory task. See Table 3.

These tasks were the same as those used by Green et al. (1994), (R10) No specific description about the tasks were made. Participants` thoughts, feelings, and sensations experienced during testing were captured via a short semistructured interview schedule. In addition, hunger and mood were measured using a short unipolar mood questionnaire.

Results in details

The cognitive performance tasks showed no significant group effects for the Tapping and RVIP tasks. On the SRT task dieters performed significantly worse or slightly worse than the nondieters before and after food consumption. On the Memory task dieters did not perform as well as nondietes and their performance declined significantly after eating the chocolate bar.

Questionnaires

Dieters had a significantly higher body mass index (BMI) and significantly higher RRS scores compared with nondieters.

Summary

The findings of the study mirrored and extended those of previous studies showing impaired cognitive performance in dieters. The results provided support for preoccupation as a cause of dieters` poorer performance, which was also concluded by Green and Rogers (1998), (see 8.1). Memory performance was more impaired among dieters after the food consumption. Whereas non-dieters showed unchanged memory performance. Moreover, dieters expressed a considerable increase in the number of food and dieting-related thoughts. Some dieters attributed their poorer performance to preoccupation with these thoughts.

The explanation, that deficits of cognitive performance are due to the metabolic consequences of food deprivation could not be generally supported by the results of this study. There was no improvement in memory or SRT performance after food consumption, even though, the authors explained these tasks are sensitive to alterations in blood glucose levels. Furthermore, the weight loss reported by the dieters was modest and they were not more acutely food deprived than the nondieters.

The results of the Tapping task did not differ significantly between the groups and was not altered after food consumption.

The authors explained that this was also found in previous studies „and supports the conclusion that the dieting-related deficits on cognitively demanding tasks are not due to a general slowing of motor ability or lack of motivation in dieters“ (p. 191).

In this study dieters were additionally assigned to subgroups. They differed between dieters who perceived detrimental performance effects of food and dieters who perceived beneficial performance effects. Both groups reported their actual performance reasonably accurately. The authors suggested that there is the existence of other important individual differences among the dieters. The dieter-group who perceived detrimental performance effects of food reported more food and dieting-related thoughts after the food consumption and they were heavier and scored substantially higher on the Revised Restraint Scale, indicating that they were relatively unsuccessful dieters.

In terms of considerable variability in thoughts about the impact of food and dieting-related thoughts reported by the participants the authors recommended that responses may be modified considerably according to the particular dieting attitude adopted by the individual.

8.3 Green et al., 2003. Impairments in working memory associated with naturalistic dieting in women: no relationship between task performance and urinary 5-HIAA levels.

The study was conducted in the United Kingdom. The aim of this study resembles the study above, but extended the above investigations by the question of whether impairments of working memory characteristics of dieting to lose weight can be explained in terms of preoccupying cognitions relating to body shape or to alterations in serotonergic function resulting from a low dietary intake of tryptophan (see summary for explanation). Participants were 53 female employees, between 20 and 46 years. The findings largely confirmed previous findings of a central executive and phonological loop deficit in currently dieting participants. The results sustain the hypothesis that these deficits are due to preoccupying cognitions concerning body shape.

Study design and cognitive tests

Participants were individually tested during the morning. During this session three cognitive performance tasks (two computer based and one non-computer based) were completed by each participant, each of which selectively loaded on to a different sub-component of the working memory system (same tasks were used by Green & Rogers (1998), (see 8.1). In addition, participants completed a number of self-report measures of eating behaviour, body shape concern, somatic sensations and recent dieting history. Furthermore, urine samples of each participant were analysed on HIAA (as a marker of changes in plasma tryptophan).

The tests took place in the following order: Mental Rotation task, Letter String Recall task, Tower of London task, and Self-report measures. See Table 3.

Based on the self-reports participants were assigned to three groups: 1. current dieters (19 subjects), 2. lower restrained / non-dieters (23 subjects), and 3. higher restrained / non-dieters (11 subjects). Self-report measures comprised a modified version of the Dutch eating behaviour questionaire (DEBQ), the Body Attitudes Questionnaire (BAQ), and a questionnaire assessing dieting history over the previous 12 months. For assessment of affective state the Hospital Anxiety and Depression Scale (HADS) was used.

Results in details

On the Tower of London task dieters displayed significantly longer planning times than either group of non-dieters in the four and five move problems (the two most difficult sets of problems on the task).

Questionnaires

The questionnaires revealed that current dieters had greater degrees of feelings of fatness than both groups of non-dieters. They had greater degrees of body dissatisfaction than lower restrained non-dieters, a greater personal salience of body shape related issues than both of the non-dieting groups, and higher degrees of lower body fatness than lower restrained non-dieters. Dieters also showed a higher BMI than lower restrained nondieters. Dieters reported more attempts of weight loss by dieting over the previous 12 month than non-dieters.

Summary

5-HIAA can be used as a marker of changes in plasma tryptophan. The amino tryptophan is a precursor for the neurotransmitter serotonin (5-HT respectively 5-HIAA). Findings of previous studies revealed the assumption that „the impairment in cognition observed in naturalistic dieting are the result of low dietary intakes of tryptophan and, by implication, lower levels of 5-HT synthesis“ (p.146).

The study findings presents three important aspects: .

1. Only on the Tower of London task a significant group effect was found, with dieters displayed significantly longer planning times than either group of non-dieters in the two most difficult sets of problems on the task. This result is associated with a selective impairment in the central executive component of working memory. But no impairment was found in the visuo-spatial sketchpad

function or with any univocal evidence of a phonological loop dysfunction. These findings were also found partially by Green & Rogers (1998), (item 8.1).

2. There were significant relations between planning time on the Tower of London task and a number of aspects of participants` self-reported body shape related concerns (BAQ feelings of fatness subscale) and objectively measured body weight. Also a number of other measures were revealed to significantly predict Tower of London task performance. Thereby BMI was the most significant variable and „this being consistent with increasing weight related concern and, therefore, weight related preoccupation“ (Gibson & Green, 2002; p. 151; R11). Aspects of body shape related concern such as the salience of body shape related issues, dietary restraint and body shape disparagement were also revealed to be significant predictors of the Tower of London task. This was also the case with the number of diets attempted over the previous year. „This latter finding may indicate that low body shape related self-esteem (and the associated negative preoccupying cognitions) related to repeated, unsuccessful attempts at weight loss (...) are a significant variable in reducing available central executive capacity“ (p. 151).

The authors stated that BMI is proposed to be the major mediating variable underlying the observed effect on central executive function since it acts as a proxy measure for body shape related self-esteem and physical evidence of a past history of failed attempts at weight loss. Further they explained there is a body of confirmatory evidence to suggest that this hypothesis my indeed be the case. With regard to their results they emphasized, whilst BMI is a significant factor in influencing central executive function of dieters, it is the actual current dieting status which is the primary mediating variable.

3. The analysis of urinary 5-HIAA revealed a lack of any group differences.

This study demonstrated results which replicated the findings of a working memory deficit associated with dieting. Moreover their data strengthened the hypothesis that these deficits are due to preoccupying cognitions concerning body shape, by examining the exact nature of this effect. Green and colleagues recommended that future work will need to directly assess the relationship between task performance and plasma tryptophan levels in naturalistic dieting.

In addition, they suggested that future studies may include the use of multiple measures of the three components of working memory in order to explore the possibility that the null effects of the phonological loop and visuo-spatial sketchpad tasks observed in their study may have been due to task related variables.

8.4 Vreugdenburg et al., 2003. The effect of self-initiated weight-loss dieting on working memory: the role of preoccupying cognitions.

The study was conducted in a laboratory research in Australia. The aim was to examine the effects of weight loss dieting on the phonological loop and central executive and to extend previous work by investigating the mediating role of preoccupying cognitions concerning food, diet and body shape in the link between weight-loss dieting and working memory. Participants were 40 women between 40 and 50 years. The results indicated that performance on the components of working memory was more poorly in dieters compared to non-dieters. Proccupying thought were significantly more expressed in dieters than in non-dieters, „which mediated the relationship between dieting status and functioning of the central executive and phonological loop, and particularly of the phonological store“ (p. 291).

Study design and cognitive tasks

The study used a mixed-model design with a between-subjects factor and within-subjects factors. Each participant was tested individually. The cognitive tasks to assess working memory were administered using a dual-task procedure with Mental arithmetic as the primary task and three secondary tasks: Articulatory Suppression, Spatial Tapping, Random Generation. In addition, Phonological Similarity effect, Word length effect, Matrix reasoning task, and Spot the Word was conducted. (The last two test are not considered in the study at hand, because they do not concern memory or attention, especially). See Table 3.

Based on questions about the dieting status they were assigned into two groups: 20 dieters (currently dieting to lose weight) and 20 non-dieters (not currently dieting). In addition, questionnaires were used to gather various information about demographics, health, habits, dieting behaviour, dietary restraint (via the Dutch Eating Behaviour Questionnaire (DEBQ)), and depressive symptoms (via the Centre for Epidemiological Studies-Depression Scale). The measures of preoccupying cognitions comprised 20 statements related to thoughts about food and body shape.

Results in details

The dual task conditions for time latencies revealed that dieters took significantly longer in the articulatory suppression and random generation conditions compared to non-dieters. The percentage of errors in the articulatory suppression and the random generation conditions revealed higher results for dieters than for non-dietes. On the Phonological Similarity Effect task, dieters recalled fewer letter strings than non-dieters for both visual and auditory presentation modalities.

Questionnaires

The questionnaires revealed that current dieters expressed significantly higher levels of restraint, had dieted more frequently and had lost more weight over the past year in comparison to non-dieters.

Summary

Based on the result that current dieters took significantly longer and produced more errors compared to non-dieters when performing mental arithmetic problems concurrently with articulatory suppression and random generatio the authors suggested that the performance of dieters on working memory tasks is impaired due to specific effects on the functioning of the phonological loop and central executive, but not the visuo-spatial sketchpad. This finding of a selective impairment of working memory is consistent with the findings of Green & Rogers (1998), (see 8.1), Green et al. (2003), (see 8.3) and Poenicke et al. (2005), (see 7.3).

The authors stated, that furthermore, the results highlighted that these working memory deficits were not the result of impairments in dieters` general cognitive ability, as there were no significant differences between groups on the Matrix Reasoning task.

Related to the lack of an interaction between dieting status and phonological confusability (as part of the Phonological Similarity task) and between dieting status and Word length the authors pointed out that there are no functional deficits in either of the phonological loop sub-components due to dieting. However, in general dieters performed the Phonological Similarity Effect task significantly more poorly compared to non-dieters, which was also found by Green & Roger (1998). Vreugdenburg and colleagues suggested this finding indicates that the limited capacity of the phonological store may be affected by dieting. The Word Length Effect task revealed no significant differences between dieters and non-dietes.

The hypothesis of the authors that the observed impairments in the working memory component would be attributed to preoccupying cognitions surrounding dieting was proved by demonstrating that dieters displayed significantly higher levels of preoccupying thoughts surrounding food, diet and body shape. Vreugdenburg and colleagues summarized that their results confirm preoccupying cognitions are essentially verbal in nature, but also consume attentional resources. Finally, they suggested that individuals who are on self-initiated weight loss diets may think about the process of dieting to the detriment of efficient working memory processing. They recommended that further research should investigate whether being on a prescribed diet may alleviate this effect and whether

other factors, such as general self-control could moderate the effects of preoccupying cognitions on working memory.

8.5 Shaw & Tiggermann, 2004. Dieting and working memory: Preoccupying cognitions and the role of the articulatory control process.

The study was conducted in Australia, in a school room. The aim was to extend previous research demonstrating deficits in cognitive function among dieters, by testing the phonological loop sub-components of working memory more directly by incorporating separate measures for each component. Participants were 92 female untergraduate students with a mean age of 23.73 years. Results showed there was no effect on the phonological store due to current dieting to lose weight, suggested by the lack of effect on the Phonological Similarity Effect. While dieting affected the articulatory control process, by demonstrating a substantial reduction in the word length effect. This effect was partially mediated by preoccupying thoughts, concerning food, weight and body shape. These findings were also found with non-dieters under conditions of articulatory suppression.

Study design and cognitive tasks

Participants were tested individually. Cognitive tasks were the Phonological Similarity Effect task with auditory presentation to measure the phonological store and the Word Length Effect task to measure the articulatory control process. Both tasks were performed twice, in the absence of and in the presence of articulatory suppression. See Table 3.

A series of self-report measures followed. This comprised the Dutch Eating Behaviour Questinnaire (DEBQ) to measure dieting behaviour and several questions related to thoughts concerning food, weight and body shape. Based on the self-report, participants were assigned into three groups: Group 1: current dieters (19 participants), Group 2: past dieters (29 participants), Group 3: never dieters (44 participants). In addition, depressed mood was assessed by the depression subscale of the Depression Anxiety Stress Scale (DASS).

Results in details

On the word length effect related to dieting status, never dieters displayed more correct recall than current dieters. Also, current dieters showed a significantly smaller magnitude of the word length effect (difference between short and long word sequences) than past or never dieters.

On the word length effect related to articulatory suppression never dieters displayed a significant smaller word length effect with articulatory suppression than without suppression.

Questionnaires:

The self-report measures about preoccupying cognitions revealed that current dieters had higher levels of preoccupying cognitions than past or never dieters. Current dieters scored significantly higher on restraint than the other two groups. The past dieters scored more highly than the never dieters. BMI significantly differed between the groups, whereby both current and past dieters were heavier than their non-dieting counterparts.

Summary

The result of the Phonological Similarity Effect task (with auditory presentation) showed no impact on the phonological store component of the phonological loop due to dieting. Thus, the authors argued, dieters suffer no limitation in actual short-term storage capacity.

However, dieting revealed a substantial reduction in the word length effect (differences between short and long word sequences). With regard to their finding the authors assumed that dieting behaviour directly affects the functioning of the articulatory control process. This is in contrast to Vreugdenburg et al. (2003) who found no significant differences between dieters and non-dietes in this task when using auditory and visually presentations (see 8.4).

With their finding of the articulatory controll process as the site of the cognitive impairments suffered by dieters, the authors achieved a much more specification of the set of impairment than previously research did. The authors pointed out that the real contribution of more specifying the cognitive impairment associated with dieting lies in its implication for the understanding of the underlying mechanisms.

The study not only specified the articulatory control process, but also showed that „the effect of dieting is paralleled by the effect of articulatory suppression on these same tasks. In other words, dieters (without suppression) perform like never dieters under conditions of articulatory suppression. Thus dieters` cognitive impairment is surely attributable to some kind of verbal or linguistic interference, an interference hypothesized (...) to derive from the preoccupying cognitions concerning food, weight and body shape known to characterize dieters (...)“ (p. 183). The studys` finding that preoccupying cognitions at least partially mediated the impact of dieting on the word length effect, was interpreted as support of this latter conjecture. Higher levels of preoccupying thoughts surrounding dieting were also found in dieting participants of all studies presented before.

The authors recommended a more comprehensive measure of dieting-related preoccupying cognitions, both food and weight-based, as well as more general dysfunctional cognitions. In summary, this study confirmed that dieting to lose weight is associated with impairments of the

phonological loop. Furthermore the results revealed converge to offer strong evidence for the articulatory control process as the site of cognitive impairment among dieters and for preoccupying cognitions of a verbal nature as the likely mechanism. Finally, Shaw and Tiggermann contributed their results to the theoretical understanding of the unwanted negative consequences experienced by people who engage in dieting behaviour.

8.6 Brunstrom et al., 2005. Dietary restraint and cognitive performance in children.

The experiment was conducted in a school classroom in a statefunded primary (elementary) school in the East Midlands region of the United Kingdom. Participants were 44 girls with an average age of 10.1 years. The authors initially explained that an early onset of concerns about body images and self esteem possibly results from values inherited culturally from within the family. With this correspondence between adults and children in mind this study aimed to determine wether dietary restrained children display the same kinds of cognitive impairment. The results indicated that children with high restraint scores have longer reaction times and they also tend to perform worse on the Tower of London task

Study design and cognitive tasks

All participants were tested at one day between 9:30 am and 3:00 pm on weekdays. The experimenter was a female school governor and was well known to the children. Due to the result of a pilot testing, with children could experience a lapse in attenion when confronted with computer-based tasks for a prolonged time, the computer-based tasks and the questionnaire completion were administered in an alternated form. Based on the restraint scale scores (see below) participants were divided into low-restraint group and high-restraint group.

The cognitive tasks included a modified Simple Reaction Time (SRT) task and the Tower of London (TOL) task. See Table 3.

To assess dietary restraint, an apapted version of the restraint scale of the Dutch Eating Behaviour Questionnaire was used. Subsequent the participants were asked if they had eaten breakfast on the day of testing, which food they had eaten during this meal, and also how long ago they last ate.

Results in details

The Simple Reaction Time task revealed significant longer reaction times for the high-restraint group compared to the low-restraint group. On the Tower of London task, the time to complete the set of this task was significantly longer in the high-restraint group than in the low-restraint group. Generally, older children performed significantly better.

Questionnaires:

The participants characteristics revealed a significant correlation between BMI and restraint scores. Scores on the external eating sub-scale correlated significantly with those on the emotional eating scale.

Summary

The findings of this study are consist with data from adults, by demonstrating that high-restrained girls have poorer performance on the TOL task and they also have longer reaction times. Although, the authors conceded, a comparison of TOL task performance with studies conducted with adults is problematic, because planning ability is expected to be poorer in children. However, the finding of this study that the differences between high- and low-restrained eaters are manifest primarily in terms of processing speed is consistent with previous studies (Green & Rogers, 1998; Green et al., 2003).

The study also found that dietary restraint is related to lower academic performance (see 5.), whilst reaction time and academic performance showed no relationship. The authors supposed that impairment in academic achievement might result from the accumulative effect of the disruption in attention that is caused by intermittent thoughts about bodyweight and food. With regard to their crude measure of academic performance, consisting of only a 3-point scale, the authors recommended that future studies should include a more comprehensive academic assessment as well as measures of preoccupation with food and an assessment of body-shape concerns.

In addition, Brunstrom and colleagues noted that the significant correlation between restraint scores and BMI of the examined children is conform with a key feature of restraint that dietary restriction is more likely in individuals who have a concern with their weight. Consistent with the general claim that deficits in cognitive performance appears to be mediated by psychological rather than physiological factors, the study found restraint-related impairments despite the fact that all of the participants had eaten on the day of the experiment.

In summary the study demonstrated, that with consideration of high- and low-restraint groups, the results indicated that even after controlling for age, BMI, and other Sub-scales scores, dietary restraint is a significant predictor of poorer reaction times.

The authors concluded their study provide the first evidence that young dietary-restrained girls suffer from the same kinds of cognitive performance that are found in adults populations. Based on the relative robust relationship between dietary restraint and academic performance, they pointed out that further scrutiny is needed because these associations relate to a range of important developmental issues.

8.7 Summary

The studies presented here confirm and extend the body of evidence correlating the negative effects of restained eating on cognitive performance. The findings indicate a selective impairment of the working memory and confirm that the mediating variable of deficits found in dieters consist of dieting-related preoccupying congnitions concerning weight, diet, and body shape. In contrast to the studies evaluating short-term and extended fasting, the studies described in this section often utilise the same cognitive tasks. In addition, many studies use the same questionnaires to assess preoccupying cognitions.

Dieters show a significant impairment of performance in tasks that primarily rely upon the central executive. Aspect of attention, such as longer planning times (Green & Rogers, 1998; Green et al., 2003) and longer reaction times (Vreugdenburg et al., 2003; Brunstrom et al., 2005) were found in dieters compared to non-dieters.

Dieters also show a significant impairment of performance that primarily rely upon the phonological loop subsystem of the working memory (Green & Rogers, 1998; Vreugdenburg et al, 2003; Shaw & Tiggermann, 2004). In contrast, no impairment is seen in tasks that require the visuo-spatial sketchpad subsystem (Green & Rogers, 1998; Vreugdenburg et al, 2003; Green et al., 2003). The studies of Vreugdenburg et al. (2003) and Shaw & Tiggermann (2004) produce inconsistent results with regard to which sub-component of the phonological loop may be affected by dieting. The first study reveals a dieting-related impairment on the phonological store, while Shaw & Tiggermann (2004) do not. Instead the latter find that dieting affects the articulatory control process of the phonological loop. The reason for these inconsistent results remains unclear. Green et al. (2003) recommends the use of multiple measures of the three components of the working memory for future research.

The results add further support to the hypothesis of Green & Rogers (1995) who claim that the deficits observed in dieters are related to dieting behaviour and not to pre-existing differences in cognitive functioning between dieters and non-dieters. The findings mitigate the physiological hypthesis of food deprivation leading to impaired cognitions. For example, Green et al. (2003) reveal a lack of any group differences in urinary 5-HIAA. Further, Jones & Rogers (2002) find that dieters may experience a decrease in task performance after eating a high-energy chocolate bar. They also find considerable variability in dieting-related thoughts within their study participants. Therefore they recommend further evaluations about the particular dieting attitude adopted by the individual. This corresponds with the assumption of Green et al. (2003) that it is the actual current dieting status which is the primary influencing mediating variable. While Green et al. (2003) adds that BMI is a significant factor in influencing central executive function.

The study of Brunstrom et al. (2005) is of particular interest because it examine the effects of restrained eating on childrens` performances. The results mirror the findings obtained on adults. High-restrained girls are shown to exhibit longer reaction times and also tend to perfom worse (in terms of processing speed) on a task assessing the capacity of the central executive component of the working memory. The authors appropriately state that the implications of these findings are important in regard to schooling and educational development.

9 Conclusion

The present work provides an insight into current research in the field of nutrition science. Whether food deprivation occurs accidentally (single meal omitting) or consciously (over time), the findings of the current studies indicate a proximate impairment of cognitive memory and attention. The origin of these impairments due to physiological mechanisms and the mechanisms of pre-existing psychological factors influencing cognition functions still remain controversial.

Fasting is an elastic word in terms of the current topic. The relation on physiological mechanisms appear to be characteristical for studies considering fasting. The effects of fasting on cognitive performance have to be evaluated with regard to the underlying motives indicated by the inconsistent findings of mood state within the studies referring to fasting. The underlying motives must be differentiated and defined.

Considering the given prevalence of meal omission and undernutrition in a busy society, it is indispensable to communicate the involved negative consequences of fasting and meal omitting to the public, in particular with regard to potential disadvantages in childrens`school performance due to eating patterns. Adequate nutrition must be available to all youngsters to prevent potentially long-lasting negative effects. Indeed, long-lasting effects of regular meal omitting or fasting have not been conducted.

But also the debated impacts for everyday activities (e.g. work and car driving) must be imparted. Fasting in broad terms, or in particular the regular meal omission may lead to an increased risk of developing an eating disorder. Also understanding of the influence of food components will contribute to the prevention of obesity.

Dietary restraint can be an effective means to prevent obesity. As studies show, dietary restaint to lose weight is accompanied by detrimental effects on cognitive functions, memory and attention. This might be responsible for unsuccessful attempts to lose weight. Moreover, current studies support the hypothesis that preoccupying thoughts concerning weight, body shape and eating are the mediating variable of the observed deficits. Which specific cognitive domains are affected is still debatable and remains to be ascertained.

The finding that dietary-restrained children suffer from the same kind of cognitive impairment that is found in adults is of particular interest indicating that the process of corresponding with the beauty ideal of the time commences at an early stage.

The current studies did not include recommendations for the practical implementaion of their findings. Nevertheless, it can be assumed that there are specific differences in preoccupying cognitions between successful and unsuccessful dieters. In addition, researchers suggested that if dieters are placed on a prescribed weight-loss dieting compared to a self-directed diet, it might lead to lower dieting-related preoccupation by reducing the need for the dieters to think about their diet.

The applied cognitive test have experienced a new technological computerised operations to assess cognitive performance. The observed results within this test procedure need to be replicated.

Further investigation is required to answer remaining questions. In the mean time, the findings should be disseminated to the public, in particular in programms to prevent obesity. This will allow every one who is currently, or who will be dieting, to do so based on best practices and scientific findings. Finally, obesity is a socio-cultural problem which should pertains to the whole environment.

10 Reference

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Statutory declaration

With this I, Diana Borchmann, born 20. august 1975, declare that the present thesis was made by my self. Prohibited means were not used and only the aids specified in the thesis were applied. All parts which are taken over word-to-word or analogous from literatur and other publications are quoted and identified.

Blumenthal, June 2007 Diana Borchmann