Use of the internet, computer and videogames by children and adolescents has increased dramatically over the last decade, averaging 3 hours per day in the general population [1]. Addiction is a condition characterized by compulsive engagement in rewarding stimuli, despite adverse consequences. Problematic internet use (PIU), or addiction, is characterized by excessive or poorly controlled preoccupations, urges or behaviors regarding internet use that lead to impairment or distress. Three different models have been proposed for internet addiction [2,3].

- The DSM-V task force has created a separate category of compulsive internet usage disorder from the non-specified impulse control disorder
- Some psychiatrists have argued that internet addiction should be included in the behavioral addiction spectrum since it exhibits the features of excessive use despite adverse consequences, withdrawal phenomena, and tolerance that characterize many substance use disorders. One of the major types of internet addiction is online gaming, which is classified as a behavioral addiction [2,3].

There is growing evidence for computer and videogame addiction among children that is causing concern due to its harmful physical, emotional and social consequences [2-4]. However, it has not yet been determined whether internet addiction and computer and videogame playing meet criteria for a syndrome, e.g., the DSM-V or ICD-10 definition of behavioral and psychological signs and symptoms that cause distress or impairment. Some experts, such as Morahan-Martin [5], argue that harmful use of the internet disturbs normal life and may be considered as an impulse control rather than an addictive behavior or a clinical diagnosis.

The DSM-5 working group concurred that evidence from current research does not support establishing a new diagnostic category for Problematic Internet Use (PIU). The working group moved from a broad conceptualization (along the lines of PIU) to a more narrow one, focusing primarily on pathological online gaming and avoiding use of the term “addiction.” Thus, the DSM-5 still does not offer sufficient guidance regarding how to approach individuals with suspected internet-related psychopathology or how to design or interpret research studies on this topic. Instead, clinicians and researchers have to rely on proposed definitions, along with several screening and assessment instruments developed for PIU and problematic videogame use [6,7].

The diagnostic assessment of internet or computer game dependency remains challenging. Different studies in different countries have used different scales to assess the prevalence of problematic internet use or addiction. Several questionnaires are used for diagnosis of internet addiction,
Attention deficit/hyperactivity disorder (ADHD) is a complex disorder with multiple causes including genetic and environmental factors. The condition is usually diagnosed in childhood when difficulties emerge during play and school. It is marked by deficiency of concentration, short attention span, psychomotor restlessness and impulsiveness (American Psychiatric Association) [9]. Several cross-sectional studies have shown an association between ADHD and internet addiction among children and adolescents [10-14]. ADHD has also been associated with sexual addiction [15] and gambling [16].

The purpose of the present study was to investigate the relationship between problematic internet use and ADHD or ADD among pupils in a Jewish religious school. It was predicted that participants who were diagnosed with ADHD would show higher ratings on Young’s IAT questionnaire [8], that pupils with ADHD would spend more time on the internet than those without ADHD, and that due to extensive hours on the internet, pupils with ADHD would go to sleep later than those without ADHD.

SUBJECTS AND METHODS

The study group included 100 male participants with a mean age of 13 years (SD = 0.72, range 13–15). Fifty had a diagnosis of ADHD and 50 did not; the mean age of these two groups was 13 years 9 months (SD = 0.80) and 14 years (SD = 0.60) respectively. With regard to place of birth, 96 were born in Israel and 4 abroad. The pupils underwent a psycho-didactic diagnosis and were accordingly admitted to a special school. They were also treated with medication for ADHD including methylphenidate and dextroamphetamine. These students were often admitted after several failures in other schools and were assimilated in a highly supportive environment. The study was approved by the Institutional Review Board of the University of Ariel.

Internet addiction was measured using Young’s Internet Addiction Test (IAT) [8], which consists of 20 items measuring compulsive use of the internet on a scale of 1 (never) to 6 (always). The cutoff point of internet addiction is a score of 80 and above. In our study the IAT had a Cronbach internal validity of α=0.927. The participants were also asked to indicate how many hours they spend on the internet each day and what time they go to sleep. The questionnaire had a Cronbach internal validity of α=0.88.

Table 1. Patterns of hours spent on the internet in all participants

<table>
<thead>
<tr>
<th>Hours spent on the internet every day</th>
<th>No ADHD diagnosis</th>
<th>ADHD diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3 p.m.</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>3-5 p.m.</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>6 p.m.</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 2. Patterns of sleep in all participants

<table>
<thead>
<tr>
<th>Hour going to bed</th>
<th>No ADHD diagnosis</th>
<th>ADHD diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 11 p.m.</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>2-3 a.m.</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>4:00 a.m.</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

RESULTS

A comparison of IAT scores between pupils with ADHD diagnosis and pupils without ADHD diagnosis using paired t-tests showed that the ADHD group had higher IAT scores (1, 98) = 4.018, P < 0.01. The average IAT score of the ADHD group was 2.93 (SD = 1.06) and of the non-ADHD group 2.22 (SD = 0.65).

A chi-square test comparing the distribution of hours spent on the internet showed that the group with ADHD diagnosis spent more hours on the internet than the group without ADHD diagnosis: χ² = 9.101 < 0.05. Table 1, demonstrating the patterns of hours spent on the internet by all participants, shows that more students with ADHD diagnosis spent between 1 and 3 hours a day on the internet than those without ADHD diagnosis. There was no difference between groups in the number of students who spent 3–5 hours a day on the internet. More pupils with ADHD diagnosis spent at least 6 hours a day on the internet compared to those without ADHD.

In addition, chi-square test comparing the hour of going to sleep showed that more ADHD students went to sleep after 12 p.m. than non-ADHD students: χ² =25.21, P < 0.001. Table 2, on the patterns of sleep in all the students, indicates that more pupils without ADHD went to sleep between 8:30 and 10:30 p.m. and after 11 p.m. whereas more pupils with ADHD diagnosis went to sleep between 2 and 4 a.m.

The participants used the internet for online communication and gaming but not for online sex or gambling.

DISCUSSION

This study has shown that children with ADHD are more addicted to the internet, spend more time online, and go to sleep later than those without ADHD diagnosis. The results
support existing studies that have established the association between internet addiction and ADHD. Yoo et al. [12] who studied 535 elementary school students (mean age 11.0 ± 1.0 years) found significant associations between the level of ADHD symptoms and the severity of internet addiction (measured by the IAT). Their findings also suggested that the presence of ADHD symptoms may be one of the major risk factors for internet addiction. In adolescents (grades 9 and 10), Chan and Rabinowitz [11] reported a significant association between time spent playing internet games for more than one hour a day and Young’s IAT [8] scores and ADHD symptoms of inattention but not hyperactivity. Other studies using Young’s IAT [9] in South Korea found an association between internet addiction and ADHD in 11 year old children [12]. The same finding was noted in Taiwan, using Chen’s Internet Test in adolescents [13] and among college students [14].

Why do children and adolescents with ADHD turn to the internet and computer videogames? One explanation is the need to escape from daily problems both emotionally and socially to a safe place free of demands and obligations [15]. Internet use and computer gaming were suggested as an inadequate means of coping with frustration, stress and fears [16]. Secondly, and consistent with the stress-coping mechanism, it has been suggested that in-game reinforcement and skill significantly influence a number of affective measures, most notably excitement, arousal and frustration [17]. Thirdly, excessive computer game playing may be maintained through stimulatory effects on reward and sensitization [18], similar to the long-term changes in the brain reward circuitry thought to maintain substance dependence. Computer and videogames can serve to stimulate children and adolescents with ADHD who suffer from reward deficiency syndrome (RDS) and low dopamine availability in the brain reward system [19]. RDS refers to the breakdown of several neurotransmitters in the brain that belong to the reward system and results in aberrant conduct. The theory argues that reward deficiency may predispose individuals to addictive, impulsive and compulsive behaviors [19]. Dopamine is a prevailing brain neurotransmitter that controls the sense of satisfaction and well being [20-22]. Dopamine deficiency drives individuals to engage in activities that will stimulate brain dopamine function, such as consuming drugs and alcohol, but people may also engage in computer and videogames to enhance dopamine release [2-4].

Finally, computer programs such as Online Neuroplasticity-based Training for the Remediation of ADHD in Children (ONTRAC) can actually improve cognitive ability in children with ADHD [23]. ONTRAC is designed to selectively target ADHD-specific deficits in five critical neurocognitive domains: alertness, sustained and selective attention, working memory, impulsive response control, and suppression of distracting interference. Alternatively, pharmacological treatment with stimulants has shown some efficacy in the treatment of children diagnosed with both internet addiction and ADHD [16]. A pharmacological open-label treatment study using extended-release methylphenidate in 62 Korean children with internet video game addiction and co-morbid ADHD found that after 8 weeks of treatment there was a significant reduction in measures of internet use and internet use duration, and this improvement was positively correlated with improvement in measures of attention. These findings led the investigators to suggest that internet videogame playing might be a form of self-medication for children with ADHD. Future studies should examine the efficacy of medications for treatment of ADHD occurring concurrently with internet addiction.

LIMITATIONS
The limitations of this study include the relatively small sample size, only-male participation, and lack of control over variables such as psychological treatment and medication, enrichment and intelligence, and family background.

CONCLUSIONS
This study has shown that children with ADHD are more addicted to the internet, spend more time online, and go to sleep later than those without ADHD. The psychobiological and psychosocial mechanisms that mediate this association should be investigated further, as should the impact of medications for ADHD on internet addiction. In view of the evidence showing an association between internet addiction and ADHD, clinicians, educational professionals and parents of children with ADHD should monitor use of the internet by children and adolescents.

References

Capsule

How dying tumor cells get noticed

Besides killing tumor cells directly, some chemotherapies, such as anthracyclines, also activate the immune system to kill tumors. Vacchelli et al. discovered that in mice, anthracycline-induced antitumor immunity requires immune cells to express the protein formyl peptide receptor 1 (FPR1). Dendritic cells (DCs) near tumors expressed especially high amounts of FPR1. DCs normally capture fragments of dying tumor cells and use them to activate nearby T cells to kill tumors, but DCs lacking FPR1 failed to do this effectively. Individuals with breast or colon cancer expressing a variant of FPR1 and treated with anthracyclines showed poor metastasis-free and overall survival. Thus, FPR1 may affect anti-tumor immunity in people, too.

Science 2015; 350: 972
Eitan Israeli

Capsule

Cleavage of GSDMD by inflammatory caspases determines pyroptotic cell death

Inflammatory caspases (caspase-1, 4, 5 and 11) are critical for innate defenses. Caspase-1 is activated by ligands of various canonical inflammasomes, and caspase-4, 5 and 11 directly recognize bacterial lipopolysaccharide, both of which trigger pyroptosis. Despite the crucial role in immunity and endotoxic shock, the mechanism for pyroptosis induction by inflammatory caspases is unknown. Shi and team identify gasdermin D (Gsdmd) by genome-wide clustered regularly interspaced palindromic repeat (CRISPR)-Cas9 nuclelease screens of caspase-11 and caspase-1 mediated pyroptosis in mouse bone marrow macrophages. GSDMD-deficient cells resisted the induction of pyroptosis by cytosolic lipopolysaccharide and known canonical inflammasome ligands. Interleukin-18 release was also diminished in Gsdmd−/− cells, despite intact processing by caspase-1. Caspase-1 and caspase-4, 5 and 11 specifically cleaved the linker between the amino-terminal gasdermin-N and carboxy-terminal gasdermin-C domains in GSDMD, which was required and sufficient for pyroptosis. The cleavage released the intramolecular inhibition on the gasdermin-N domain that showed intrinsic pyroptosis-inducing activity. Other gasdermin family members were not cleaved by inflammatory caspases but shared the autoinhibition; gain-of-function mutations in Gsdma3 that cause alopecia and skin defects disrupted the autoinhibition, allowing its gasdermin-N domain to trigger pyroptosis. These findings offer insight into inflammasome-mediated immunity/diseases and also change our understanding of pyroptosis and programmed necrosis.

Nature 2015; 526: 660
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