‘The Penny Drops’: investigating insight through the medium of cryptic crosswords

Kathryn J. Friedlander[1*], Philip A. Fine[1]

[1]Psychology, University of Buckingham, United Kingdom

Submitted to Journal:
Frontiers in Psychology

Specialty Section:
Cognition

Article type:
Protocols Article

Manuscript ID:
318582

Received on:
31 Oct 2017

Revised on:
30 Apr 2018

Frontiers website link:
www.frontiersin.org

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest

Author contribution statement

KF drafted the article and KF and PF reviewed and finalized it. KF designed the survey and analyzed data via an Access database. KF and PF reviewed data and agreed coding treatments.

Keywords

cryptic crosswords, Insight problem-solving, Aha! experience, Constraint relaxation, Representational change, opportunistic assimilation, chunk decomposition, Remote associations, Rebus puzzles, Jokes, Anagrams, Expertise Development

Abstract

Word count: 346

A new protocol for eliciting insight ('Aha!'/Eureka) moments is proposed, involving the solving of British-style cryptic crosswords. The mechanics of cryptic crossword clues are briefly explained, and the process is set into the insight literature, with parallels being drawn between several different types of cryptic crossword clues and other insight-triggering problems such as magic, jokes, anagrams, rebus and remote association puzzles (RAT), as well as 'classic' thematic or spatial challenges. We have evidence from a previous survey of cryptic crossword solvers that the 'Aha!' moment is the most important driver of continued participation in this hobby, suggesting that the positive emotional 'payback' has an energizing effect on a participant's motivation to continue solving.

Given the success with which a good quality cryptic crossword elicits 'Aha!' moments, cryptics should prove highly valuable in exploring insight under lab conditions. We argue that the crossword paradigm overcomes many of the issues which beset other insight problems: for example, solution rates of cryptic crossword clues are high; new material can easily be commissioned, leading to a limitless pool of test items; and each puzzle contains clues resembling a wide variety of insight problem types, permitting a comparison of heterogeneous solving mechanisms within the same medium. Uniquely among insight problems, considerations of expertise also come into play, allowing us to explore how crossword solving experts handle the deliberate misdirection of the cryptic clue more effectively than non-expert, but equally experienced, peers.

Many have debated whether there is such a thing as an 'insight problem' per se: typically, problems can be solved with or without insight, depending on the context. We argue that the same is true for cryptic crosswords, and that the key to the successful triggering of insight may lie in both the difficulty of the challenge and the degree to which misdirection has been used. Future research is outlined which explores the specific mechanisms of clue difficulty. This opens the way to an exploration of potential links between solving constraints and the experiencing of the 'Aha!' moment, which may shed light on the cognitive processes involved in insight solution.

Ethics statements

(Authors are required to state the ethical considerations of their study in the manuscript, including for cases where the study was exempt from ethical approval procedures)

Does the study presented in the manuscript involve human or animal subjects: Yes

Please provide the complete ethics statement for your manuscript. Note that the statement will be directly added to the manuscript file for peer-review, and should include the following information:

- Full name of the ethics committee that approved the study
- Consent procedure used for human participants or for animal owners
- Any additional considerations of the study in cases where vulnerable populations were involved, for example minors, persons with disabilities or endangered animal species

As per the Frontiers authors guidelines, you are required to use the following format for statements involving human subjects: This study was carried out in accordance with the recommendations of [name of guidelines], [name of committee]. The protocol

was approved by the [name of committee]. All subjects gave written informed consent in accordance with the Declaration of Helsinki.
For statements involving animal subjects, please use:
This study was carried out in accordance with the recommendations of 'name of guidelines, name of committee'. The protocol was approved by the 'name of committee'.

If the study was exempt from one or more of the above requirements, please provide a statement with the reason for the exemption(s).
Ensure that your statement is phrased in a complete way, with clear and concise sentences.

This study was carried out in accordance with the recommendations of the British Psychological Society with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the School of Science and Medicine Ethics Committee, University of Buckingham.

'The Penny Drops': investigating insight through the medium of cryptic crosswords

Kathryn J. Friedlander[1]* and Philip A. Fine[1]

[1] Department of Psychology, University of Buckingham, Buckingham, Buckinghamshire, England

* Correspondence: Dr. Kathryn Friedlander, Department of Psychology, School of Science, University of Buckingham, Buckingham, MK18 1EG, England. kathryn.friedlander@buckingham.ac.uk

Keywords: cryptic crosswords, insight problem-solving, Aha! experience, constraint relaxation, representational change, opportunistic assimilation, chunk decomposition, remote associations, Rebus puzzles, jokes, anagrams, expertise development

Author contributions: KF drafted the article and KF and PF reviewed and finalized it. KF designed the survey and analyzed data via an Access database. KF and PF reviewed data and agreed coding treatments.

Author notes and acknowledgments:

We are indebted to the editorial team at the Magpie crossword magazine (www.piemag.com) for allowing us to reproduce the crossword puzzles, editorial comments and solutions in figures 2 and 3 and the related discussion. The survey was made available on the Internet via SurveyMonkey® (www.SurveyMonkey.com, Palo Alto, CA); and we are grateful to all the owners and administrators of the websites who allowed us to advertise for participants, and to those who took part so enthusiastically.

Abstract 350 words

A new protocol for eliciting insight ('Aha!'/Eureka) moments is proposed, involving the solving of British-style cryptic crosswords. The mechanics of cryptic crossword clues are briefly explained, and the process is set into the insight literature, with parallels being drawn between several different types of cryptic crossword clues and other insight-triggering problems such as magic, jokes, anagrams, rebus and remote association puzzles (RAT), as well as 'classic' thematic or spatial challenges. We have evidence from a previous survey of cryptic crossword solvers that the 'Aha!' moment is the most important driver of continued participation in this hobby, suggesting that the positive emotional 'payback' has an energizing effect on a participant's motivation to continue solving.

Given the success with which a good quality cryptic crossword elicits 'Aha!' moments, cryptics should prove highly valuable in exploring insight under lab conditions. We argue that the crossword paradigm overcomes many of the issues which beset other insight problems: for example, solution rates of cryptic crossword clues are high; new material can easily be commissioned, leading to a

limitless pool of test items; and each puzzle contains clues resembling a wide variety of insight problem types, permitting a comparison of heterogeneous solving mechanisms within the same medium. Uniquely among insight problems, considerations of expertise also come into play, allowing us to explore how crossword solving experts handle the deliberate misdirection of the cryptic clue more effectively than non-expert, but equally experienced, peers.

Many have debated whether there is such a thing as an 'insight problem' per se: typically, problems can be solved with or without insight, depending on the context. We argue that the same is true for cryptic crosswords, and that the key to the successful triggering of insight may lie in both the difficulty of the challenge and the degree to which misdirection has been used. Future research is outlined which explores the specific mechanisms of clue difficulty. This opens the way to an exploration of potential links between solving constraints and the experiencing of the 'Aha!' moment, which may shed light on the cognitive processes involved in insight solution.

Introduction: insight and 'insight problems'

The feeling of insight - a sudden, euphoric 'cognitive snap' (Weisberg, 2015) signaling a breakthrough in the solution of a problem - is well-known to most of us. In terms of its phenomenological experience, four key elements of the insight, or 'Aha!' moment have been identified: first, the suddenness and unexpectedness of the resolution, which arrives unheralded by conscious awareness of the solution path or 'feelings of warmth' at the approaching dénouement; secondly that - however difficult it had proved before (perhaps involving a state of impasse) - the problem can be rapidly processed once the solution has been identified; thirdly that there is a strong, typically positive, emotional response at the point of resolution; and finally that the solver is fully convinced that the correct solution has been identified (Topolinski & Reber, 2010a; see also Metcalfe, 1986; Davidson, 1995; Gick & Lockhart, 1995; Danek, Fraps, Von Müller, Grothe, & Öllinger, 2014b, 2014a; Kounios & Beeman, 2014; Shen, Yuan, Liu, & Luo, 2015; on negative insight ('Uh-oh') see also Hill & Kemp, 2016). The phenomenological experience of the Aha! moment is thus complex, with at least four contributory components: suddenness, surprise, happiness and certainty (Gick & Lockhart, 1995; Danek, et al., 2014a; Danek, Wiley, & Öllinger, 2016).

One of the key problems in studying insight is the unpredictability of this moment in everyday life. Although 'everyday insight moments' can be experienced (such as the sudden realization of where a bunch of keys has been left), the sudden and fleeting nature of this moment has led most studies to attempt to elicit responses artificially under laboratory conditions, using a bank of so-called 'insight

problems' intended to trigger the identical phenomenological response (Hill & Kemp, 2016). Nonetheless, even this approach is not without issues, primarily centered upon the difficulty of finding an effective, convenient and reliable insight-triggering task for the participant to solve.

Current obstacles in exploring insight in the laboratory

Lab studies of insight in problem solving have met with a number of obstacles, which have been well rehearsed in the literature. These include the historic paucity of standardized problem material (MacGregor & Cunningham, 2008; Batchelder & Alexander, 2012; Danek, et al., 2014b); the difficulty and complexity of the tasks, leading to low solution rates and low numbers of problem trials within the practical limitations of investigative time-frames (Bowden & Jung-Beeman, 2003b; MacGregor & Cunningham, 2008; Batchelder & Alexander, 2012; Danek, et al., 2016); and the memory advantage obtained for solutions arrived at by insight (Dominowski & Buyer, 2000; Danek, Fraps, von Müller, Grothe, & Öllinger, 2013) which rules out test-retest options (MacGregor & Cunningham, 2008).

This last issue poses a particular problem for controlled, lab-based research, given that the solutions to so many of the classic riddle-style 'insight problems' (e.g. the 9-dot problem, the reversed triangle of coins, the broken necklace challenge - Cunningham, MacGregor, Gibb, & Haar, 2009 - see figure 1) are now freely available on-line and in puzzle collections; this commonly leads to the need to discard trials due to familiarity with the puzzles (Öllinger, Jones, & Knoblich, 2014; see also Danek, et al., 2016).

<Insert figure 1 somewhere here>

Following attempts to increase the pool of test material in recent years, larger collections of calibrated problems do now exist (Chu & MacGregor, 2011): these have moved away from the classic 'riddle-style' puzzles (Webb, Little, & Cropper, 2016) and might include matchstick arithmetic problems (Knoblich, Ohlsson, Haider, & Rhenius, 1999), compound remote association problems ('CRA' - a variation of 'Remote Association Test' (RAT) problems - Bowden & Jung-Beeman, 2003b), the 'Car Park Game' (Jones, 2003), rebus puzzles (MacGregor & Cunningham, 2008), Bongard problems and 'tricky series completion' problems (Batchelder & Alexander, 2012). Recently, magic tricks have been added to the list of available paradigms (Danek, et al., 2014b).

When is insight 'insight'?

The use of a canonical set of 'insight problems' to explore Aha! moments in the laboratory has led to a long-standing debate concerning the underlying cognitive mechanisms involved in their solution: specifically, whether an Aha! feeling is the result of 'special' thought processes, or is merely an epiphenomenon arising from cognitive processes which are 'business as usual' (for a review of this debate see Davidson, 1995; Bowden, Jung-Beeman, Fleck, & Kounios, 2005; Ohlsson, 2011; Gilhooly, Ball, & Macchi, 2015; Weisberg, 2015). One confounding issue which has hampered investigation of this question is the common assumption in many historical studies that 'insight problems' are, per se, always solved with insight by every successful solver; in other words, that 'triggering insight' is an inherent and objective property of the 'insight problem' which unfailingly comes into play (Bowden & Jung-Beeman, 2007; Ohlsson, 2011; Öllinger, et al., 2014). Crucially, as a result of this *a priori* assumption, no check was typically made as to whether the 'Aha!' moment had actually been experienced in these trials, leading to a highly problematic circularity: "Insight problems are problems that require insight, and insight occurs when insight problems are solved" (Öllinger & Knoblich, 2009, p.277; see also Danek, et al., 2016; Webb, et al., 2016). An early attempt (Weisberg, 2015; see Ash, Cushen, & Wiley, 2009) to circumvent this problem by categorizing 'insight problems' into 'pure' problems (those that could only be solved with insight), 'hybrid' problems (those that could be solved through insight and other methods) and 'non-insight' problems (those which are always resolved through an analytical approach) nonetheless still requires that a subset of problems exists which infallibly trigger insight.

A critical flaw in this approach is that it overlooks the interactive nature of problem solving: successful solving arises from the interplay of problem and person, with each individual bringing an unique blend of knowledge, experience and cognitive approaches to bear upon it (Ash, et al., 2009; Ohlsson, 2011). It is therefore entirely possible for a so-called 'insight puzzle' to be solved through controlled, deliberate, systematic and evaluative means by some solvers - analytic 'Type 2' thinking according to dual process theory (Evans & Stanovich, 2013; Sowden, Pringle, & Gabora, 2015; Weisberg, 2015) - which is not thought to give rise to a characteristically strong emotional response, other than satisfaction at the job completed (Kounios & Beeman, 2014).

Others, however, may solve the same puzzle with a flash of inspiration that they could not predict, through processes operating below the threshold of their awareness, and will experience the impact of the Aha! moment. Much will depend on what each solver brings to the solving process: "each problem can be solved without insight if the initial problem representation is adequate and the appropriate heuristics are available" (Öllinger, et al., 2014 p.267), and this will vary from solver to

143 solver according to their skill-set and experience. The presence or absence of insight thus resides in
144 the solver's approach to solving the puzzle, not simply in the problem itself (Bowden & Jung-
145 Beeman, 2007; Cunningham, et al., 2009; Webb, et al., 2016), and the categorization of 'insight
146 problem' stimuli as 'pure' or 'hybrid', or 'insight/non-insight' on the grounds of a hypothetical
147 cognitive task analysis appears to be fundamentally flawed (Ash, et al., 2009; Webb, et al., 2016).
148
149 The purpose of insight research should not therefore be to develop a single theory which accounts
150 for all solutions to 'insight problems' arrived at by any manner under experimental conditions
151 (Ohlsson, 2011), but to isolate those solutions which have evoked the phenomenological events
152 specifically characteristic of an Aha! event, and to use these to explore the cognitive mechanisms
153 underlying this experience (Webb, et al., 2016). More contemporary studies have typically achieved
154 this by collecting subjective feedback from trial participants as to whether they have actually
155 experienced an 'Aha!' moment at the point of solution (Bowden & Jung-Beeman, 2007; Kounios, et
156 al., 2008; Cranford & Moss, 2011; Jarosz, Colflesh, & Wiley, 2012; Danek, et al., 2014b; Salvi,
157 Costantini, Bricolo, Perugini, & Beeman, 2016; Webb, et al., 2016). This technique has been validated
158 by a number of neuroimaging studies, which have empirically demonstrated meaningful differences
159 between problems identified by participants as being solved with insight, or in a step-wise fashion
160 (Zhao, et al., 2013; Kounios & Beeman, 2014).
161
162 **Representational Change Theory**
163 Notwithstanding this, it would be unhelpful to reject the term 'insight problem' altogether, given
164 that it is clear that some cognitive puzzles are more likely to trigger insight moments than others
165 (Danek, et al., 2014a), and indeed 'insight problems' may operate along a continuum of efficacy
166 (Webb, et al., 2016). In particular, Representational Change Theory ('RCT' - Ohlsson, Ernst, & Rees,
167 1992; Knoblich, et al., 1999; Ohlsson, 2011; Öllinger, et al., 2014) suggests that especially effective
168 insight-triggering puzzles use the solver's prior knowledge and expectations to deliberately induce a
169 false conceptualization of the problem (Ovington, Saliba, & Goldring, 2016), leading to self-imposed
170 constraints which impede a solution. This can result in a feeling of 'impasse': the situation where the
171 solver feels that they have explored all possible approaches to resolving the problem, and is now at a
172 loss as to what to try next (Knoblich, Ohlsson, & Raney, 2001).
173
174 The moment of insight is argued to be the point at which the hindering constraint is suddenly
175 removed, leading to a relaxation of the impasse and the rapid redefining of the problem space,
176 followed by a swift solution. The initially incorrect reading of the problem - termed '*mental set*' by

the Gestalt school (Wiley, 1998; Öllinger, Jones, & Knoblich, 2008) - is argued to arise unavoidably and unconsciously from implicit assumptions or well-practiced procedures which are activated highly automatically (Ohlsson, et al., 1992; Knoblich, et al., 1999; DeYoung, Flanders, & Peterson, 2008; Öllinger, et al., 2008; Danek, et al., 2014b; Patrick, Ahmed, Smy, Seeby, & Sambrooks, 2015), making the less obvious, but correct, interpretation of the problem very unlikely to come to mind. It is the dropping of the incorrect assumptions, and disengagement from the outdated hypothesis, which is argued to allow progress to be made.

Heterogeneous Nature of Insight Puzzles and their Mechanisms

It is thus widely acknowledged that 'insight problem' solving involves some form of reconstructive change of the initial representation of the problem (Chronicle, MacGregor, & Ormerod, 2004; Cunningham, et al., 2009; Danek, et al., 2014a); however, the precise mechanisms to achieve this reconstruction - and whether they are in any way 'special' - remain unclear.

A number of theoretical models to explain this restructuring in classic insight puzzles, such as the 9-dot or the 8-coin puzzles, have been put forward: for example 'elaboration, re-encoding or constraint relaxation' (Ohlsson, et al., 1992); 'opportunistic assimilation' (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995); 'constraint relaxation and chunk decomposition' (Knoblich, et al., 1999); 'solution-recoding' (Chronicle, et al., 2004); see further the reviews by Ash, Cushen, & Wiley (2009) and Batchelder & Alexander (2012). Nonetheless, since the formulation of these theories, a wider range of insight-triggering paradigms has been developed which on at least superficial grounds differ greatly in their appearance and the demands they make upon the solver (Bowden, et al., 2005). It is therefore at least possible that the cognitive processes leading up to the moment of restructuring differ according to the specific puzzle parameters at play (Bowden & Jung-Beeman, 2007), making a single-process theory of restructuring difficult (Cunningham, et al., 2009).

In a study comparing the relationships among a small range of diverse insight puzzles (classic 'spatial' puzzles, RAT puzzles and rebus problems), Cunningham and colleagues identified the following characteristics of restructuring which they believed were displayed, to a greater or lesser extent, by each of their puzzle formats of interest (Cunningham, et al., 2009). As predicted by RCT, some puzzles involved the need to overcome misdirection or the relaxation of automatically elicited constraints concerning the existing components of the puzzle or its spatial layout (Cunningham, et al., 2009). However, in others, the primary difficulty appeared to lie in identifying what the eventual solution would look like, perhaps requiring the assimilation of extra incidental information, a sudden

'figure-ground' reversal of perspective, or additional steps in order to hit upon the solution (Cunningham, et al., 2009).

One methodological issue thus lies in how 'well-defined' a problem type is (DeYoung, et al., 2008; see also Simon, 1973; Pretz, Naples, & Sternberg, 2003; Davidson, 2003; Hélie & Sun, 2010; Danek, et al., 2016; Ovington, et al., 2016; Webb, et al., 2016). An ill-defined problem has no clear representation of the problem space in terms of key features such as the initial conceptualization of the challenge, the final goal state, and the mechanizable steps which need to be taken to achieve this goal. By contrast, 'well-defined' problems may be tackled by controlled and systematic paradigmatic processes leading to steady progress towards a known target state (Smith, 2003; DeYoung, et al., 2008), and better defined problems of this kind therefore lead less often to solution through insight (Webb, et al., 2016).

Despite early attempts to categorize insight puzzles (e.g. as pure/hybrid) according to solving process (Ohlsson, et al., 1992; Weisberg, 1995; Ansburg & Dominowski, 2000), the heterogeneous nature of the various problem collections therefore makes equivalence studies difficult (Weisberg, 1995; Cunningham, et al., 2009), and this limits our understanding of the core components of problem solving with insight (Bowden & Jung-Beeman, 2003b; MacGregor & Cunningham, 2008). Attempts to find one single explanation of the cognitive processes leading to insight solution by pitting alternative theories against each other on a single puzzle type (e.g. Jones, 2003) may on this account be doomed: it is entirely possible that insight could arise from different interacting sets of preceding processes depending upon the context and the challenge inherent in the problem and that these processes may only imperfectly map onto these traditional problem type categories (Bowden & Jung-Beeman, 2007; Shen, et al., 2016). A theoretical or computational model of 'insight problem' solving which satisfactorily explains all facets and styles of insight challenge is therefore proving elusive (Ash, et al., 2009; Batchelder & Alexander, 2012).

Rapid Solving and Incubated Problems

Equally vexed is the question of whether a period of impasse is always involved in 'insight problem'-solving (as argued e.g. by Ohlsson, et al., 1992), with some studies reporting that - even within puzzle type - solvers did not uniformly experience a period of impasse (Cranford & Moss, 2012; Ash, Jee, & Wiley, 2012; Danek, et al., 2014a).

Indeed, studies have suggested that solvers can experience an instantaneous 'Aha!' moment within seconds of the presentation of the puzzle. In a study of anagram solving, Novick and Sherman noted that 'pop-out' solutions tended to be the first solution offered and to occur within 2 seconds of the presentation of the letters (Novick & Sherman, 2003). In trials of highly skilled anagram solvers, 47% of the solutions were reported to be immediate 'pop-out' solutions, where the solver agreed that, "The solution came to mind suddenly, seemingly out of nowhere. I have no awareness of having done anything to try to get the answer." By contrast 27% of solutions occurred with insight after a period of trying fruitless combinations; and 26% were generated incrementally by the recursive testing of morphemically probable combinations (non-insight search solutions).

Similarly, a study of RAT problems (Cranford & Moss, 2012), found that 171 out of 218 solutions arrived at with self-reported insight, under think-aloud conditions, were solved almost immediately, in a mean time of 7.1 seconds. These were categorized as 'Immediate Insight' (II) moments; however, the authors also raised the possibility that the solution might simply have occurred so fast that it appeared sudden and surprising, without evoking the full phenomenological experience (Cranford & Moss, 2012; see also Topolinski & Reber, 2010b). Indeed, an fMRI study comparing II with Delayed Insight (DI) RAT solutions showed large differences in activation patterns for the two types of insight, suggesting that they may represent distinct solution processes (Cranford & Moss, 2011). For this reason, some later studies have excluded II solutions from their discussion, on the grounds that they may not reflect the full "Aha!" experience (e.g. Salvi, Bricolo, Kounios, Bowden, & Beeman, 2016).

Conversely, the benefits of a period of incubation (non-conscious solving activity, or a period of respite away from the problem) in resolving problems which have reached impasse have been well-documented (see the meta-analytic review by Sio & Ormerod, 2009; also Ohlsson, 2011; Baird, et al., 2012; Sio & Ormerod, 2015; Gilhooly, 2016), although the mechanisms which account for the facilitation of the solution (e.g. 'unconscious work', 'intermittent work', 'beneficial forgetting' - Gilhooly, 2016) are as yet unclear. Incubation is clearly not always involved in insight problem resolution - though it was present as the second of Wallas' (1926) four stages of insight problem-solving (Sio & Ormerod, 2009) - and is rather seen as an ancillary feature, to be utilized where necessary (Gilhooly, 2016). Engaging in a diversionary activity with a low cognitive load appears to be most helpful (Sio & Ormerod, 2009), and many people report that the problem solution occurs to them when engaged in everyday activities such as walking, driving or showering (Ovington, Saliba,

Moran, Goldring, & MacDonald, 2015; Hill & Kemp, 2016); a substantial number also report facilitation overnight, during their dreams or immediately upon waking (Ovington, et al., 2015).

Cryptic Crosswords as potential triggers of Insight

Cryptic (British-style) crosswords afford a unique opportunity to explore the mechanisms of insight and the issues highlighted above within an existing, readily available puzzle format. Devised in the mid 1920's (Connor, 2014), cryptic crosswords employ an extensive variety of highly ingenious puzzle mechanisms, many of which also draw on shared characteristics with a range of other types of 'insight problem' (see review below). One puzzle may thus encapsulate a wide range of these mechanisms, presenting a compendium of heterogeneous insight challenges unrivalled by any other insight puzzle format. Studying cryptic crosswords may therefore enable us to understand better the antecedents, solving processes and key triggers of the insight moment.

What are 'cryptic crosswords'?

The nature of the cryptic crossword has been described in some detail in an earlier paper (Friedlander & Fine, 2016), but key aspects are highlighted again below. Example cryptic crossword clues, together with an explanation of the cryptic instructions for achieving the required solution, are set out in **Boxes 1, 2, 4, 5 and 6. <insert box 1 somewhere around here>**.

Unlike their 'straight definition' American cousins, the challenge of the British-style cryptic crossword lies not in the obscurity of the vocabulary to be retrieved, but in the quasi-algebraic coded instructions which must be executed precisely in order to achieve the correct answer to the clue (Friedlander & Fine, 2016): see Box 1. Cryptic crossword clues usually comprise two elements: a straight definition, plus the cryptic instructions for assembling the required solution—the "wordplay" (Friedlander & Fine, 2016; Pham, 2016). It is not always obvious which part of the clue is fulfilling what role, and there is often no clear division between the two parts (Friedlander & Fine, 2016). Even the 'definitional' element of the clue might be obliquely or whimsically referenced, consciously exploiting ambiguities such as grammatical form, phrasal semantics, homophones, synonyms and roundabout expressions (Cleary, 1996; Aarons, 2015; Friedlander & Fine, 2016). The clue type also has to be identified and interpreted. All these factors mean that that cryptic crosswords are typically ill-defined in both problem conceptualization and solution methodology (Johnstone, 2001).

Each cryptic crossword clue is thus a tricky linguistic puzzle using non-literal interpretations of deconstructed clue components in a 'truly slippery and fundamentally ambiguous' fashion (Aarons,

2012, p.224), stretching the conventions of everyday speech at all levels of structure and context (Aarons, 2015). The misdirection is deliberate: the surface reading of the clue evokes our tacit knowledge of language to suggest a plausible, yet unhelpful, interpretation of the clue (the 'red herring'), setting up a constraint which must be resolved for progress to be made (Aarons, 2015; Friedlander & Fine, 2016). Once accomplished, the 'Aha!' experience is triggered: this is termed the 'Penny Dropping Moment' or 'PDM' by crossword solvers (Friedlander & Fine, 2016).

In this use of misdirection, cryptic crosswords are similar to magic tricks: in both areas, the practitioner exploits implicit assumptions of the audience which are activated highly automatically, either (in magic) because of long-term exposure to the natural laws governing everyday life, such as gravity (Danek, et al., 2014b) or (in crosswords) because of a lifetime's parsing habits as a reader and interpreter of standard text (Schulman, 1996). The task of the setter, as for the magician, is to conceal the clue mechanism so subtly that the pathway is not readily detectable (Friedlander & Fine, 2016).

Once deconstructed in this manner, there is no requirement for the cryptic components to make further sense as a coherent whole: the beguilingly smooth surface reading of the clue is typically abandoned in favor of a *potpourri* of dissociated cryptic fragments, each serving a quite different purpose entirely ungoverned by word-order, grammatical or orthographic considerations (Pham, 2016). In this way cryptic crosswords can be seen as a type of 'non-*bona fide* communication' (Aarons, 2015, p.357): the solver understands that the normal rules of communication must be temporarily suspended (just as they are required to suspend disbelief at a magic show), and that the clue itself is simply a vehicle for the intellectual challenge of solving the clue.

Range of cryptic clue challenges and parallels with other insight problems

Although there is general agreement that the clues have to be fairly constructed (i.e., unambiguously solvable), there are no hard-and-fast guidelines as to what the rules of engagement are (Aarons, 2015; Friedlander & Fine, 2016), leading to an almost infinite number of innovative ways to exploit the "versatile and quirky English language" (Connor, 2013). Nevertheless, there is some consensus over a number of basic mechanism types, and a range of "Teach-Yourself" primers exist (Friedlander & Fine, 2016; see also now the on-line solving channel - Anthony & Goodliffe, vlog). A brief review of the most striking parallels between a variety of insight puzzles and the mechanics of solving cryptic crosswords follows.

Jokes and cryptic crosswords: deliberate misdirection

Individual differences in the ability to appreciate humor have been previously identified (Cunningham & Derks, 2005; Kozbelt & Nishioka, 2010; Dunbar, Launay, & Curry, 2016) and cryptic crossword solvers appear to be particularly attuned to and to enjoy verbal ambiguity and wordplay. In a study involving solvers and non-solvers (Underwood, MacKeith, & Everatt, 1988) the strongest correlation associated with cryptic puzzle-solving was the frequency of incidentally elicited laughter during an experiment involving associative priming (e.g. 'strawberry' priming 'traffic' through the unpresented word 'jam').

Linguistic jokes share many characteristics with cryptic crosswords, including deliberate misdirection (Aarons, 2015), and - although only rarely used as such in the lab - jokes have been identified as a type of insight puzzle (Gick & Lockhart, 1995; Ramachandran, 1998; Robertson, 2001; Kounios & Jung-Beeman, 2009; Kozbelt & Nishioka, 2010; Amir, Biederman, Wang, & Xu, 2015) on the basis of the suddenness and rapidity of the solution, the lack of 'feeling-of-warmth', the pleasant feelings evoked at the moment of understanding, and the feeling of certainty in the correctness of the solution. A punning joke is typically based on two alternative interpretations of a scripted feed-line, which are both plausible in some sense, however absurd, 'until the punchline, which highlights the initially less obvious one, and reveals the other to be a dummy, designed intentionally to mislead the listener' (Aarons, 2015, p.352).

Working in a parallel tradition to that of psychological insight studies, linguistic humor studies have long explored the operation of jokes in the context of a two-stage process of 'Incongruity-Resolution' (for a review see Forabosco, 2008), which shares many points of similarity with RCT. 'Incongruity-Resolution' proposes that the expectations of the joke's audience are deliberately manipulated to predict a sensible, but incorrect outcome, making the actual punchline initially unexpected or incongruous (the 'surprise' phase). In the second phase (termed 'coherence'), the listener then engages in a rapid form of problem-solving in order to revisit and resolve the incongruity, enabling the punchline to make plausible sense once it has been reconciled with an amusing and perhaps off-beat alternative interpretation of the original joke setting (Suls, 1972; Bartolo, Benuzzi, Nocetti, Baraldi, & Nichelli, 2006; Forabosco, 2008; Hurley, Dennett, & Adams, 2011; Canestrari & Bianchi, 2012). In other words, they must backtrack to search for an implicit constraint in their interpretation of the joke wording, which can be relaxed sufficiently to accommodate both the joke setting and its punchline within a revised interpretative structure (Suls, 1972; Navon, 1988). This process takes only a short time: there is an inverted relationship between

speed of appreciation and funniness ratings (Cunningham & Derks, 2005; Kozbelt & Nishioka, 2010), and a joke falls flat if the explanation is too labored (Kozbelt & Nishioka, 2010).

If interpreted literally, the initially less dominant meaning ('latent content' - Kozbelt & Nishioka, 2010; Erdelyi, 2014) underpinning the correct interpretation of the punchline is often inappropriate, impossible or surreal: an 'as if' resolution (Navon, 1988; Amir, et al., 2015) which is "seemingly appropriate but virtually inappropriate" (Navon, 1988, p.210) and - as for cryptic crosswords and magic tricks - functions "only on account of a willing suspension of disbelief" (Attardo, Hempelmann, & Di Maio, 2002, p.5). It is at this point that we experience the emotional payback, as we 'get' the joke, with the sudden, absurd resolution eliciting laughter; recent studies have begun to explore the neural correlates of these humorous insight moments (Amir, et al., 2015; Chan, 2016).

The workings of this mechanism are exemplified in the following joke:

> *'So, I bought some animal crackers, and the box said:*
> *"Do not consume if the seal is broken"…' (*attrib. Brian Kiley)

Here, the listener is primed to interpret the term 'seal' in terms of the intact packaging containing the foodstuff. The punchline seems incongruously out of place given that a joke is ostensibly being recounted: it appears to be a banal repetition of standard wording commonly found on packaged goods, and is not inherently amusing. The feeling of 'missing something' - that "*nagging* sort of anxiety when you sense that something is funny-huh" (Hurley, et al., 2011, p.79) evokes an uncomfortable state of incongruity akin to cognitive dissonance (Festinger, 1957; Forabosco, 2008; Yim, 2016), and this discomfort will provide the motivational drive to reconcile or reduce the perceived inconsistency by reassessing the initial interpretation of the joke setting. It is only upon reinterpreting the word 'seal' (in the context of 'animal crackers') that the alternative and nonsensical latent content of the joke emerges: that the crackers should not be eaten if the seal biscuit is broken.

Similarly, the cryptic crossword clue at Box 2(a) leads initially to a deceptively straightforward solution ('Scared stiff'), which perhaps only subsequently reveals the underlying pun 'Stiff -> Corpse -> Frightened to death', confirming the accuracy of the solution.

<INSERT BOX 2 SOMEWHERE HERE>

Fundamental to punning humor of this nature is the concept of 'bisociation' – the perceiving of a situation in two incompatible frames of reference (Koestler, 1964; Dienhart, 1999; Canestrari & Bianchi, 2012). Following this account, ambiguous phonetic forms such as homophones, homonyms and polysemes can act as triggers which abruptly switch the listener from one semantic script (e.g. 'seal = box packaging') to another (e.g. 'seal = biscuit shape'). Koestler sees this as a sudden 'Gestalt' reversal (Koestler, 1964).

Key to the workings of the joke or crossword clue is the initial concealment of the alternative meaning; and indeed it is a general feature of insight puzzles that the solution typically involves a statistically infrequent response, such as an unusual use for an object, or a less familiar, less dominant meaning for a word or phrase (Dominowski, 1995). So, for example, the cryptic crossword clue at Box 2(b) requires the solver to recognize that a potential solution word ('unearthed'), in its prototypical sense of 'discovered', has a second, non-intuitive but highly appropriate role to play in the clue ('without an earth wire').

The cryptic crossword solver is thus often gulled into a readily available, but false interpretation of the clue setting (the 'surface reading') based on a *prima facie* interpretation of everyday linguistic rules, ambiguous phonetic forms, learned phraseological conventions, and context. This approach leads initially to nagging puzzlement, impasse and cognitive dissonance, since the original interpretation cannot be made to yield the desired answer (the solver is 'missing something'). This provides the motivation to detect and explore alternative interpretations (some perhaps fruitlessly) in order to arrive at the moment of insight. As with jokes, the cryptic crossword's 'pay-off' (the final understanding of the clue) arrives when the original constraints are abruptly overturned in favor of a switch to an alternative, non-intuitive reading of the cryptic elements - often leading to surprise, laughter and the delight of the PDM (Aarons, 2015). No matter how lengthy and difficult this problem-solving phase has been, the clue is typically processed rapidly once the constraint is cracked (Topolinski & Reber, 2010a).

Rebus puzzles and cryptic crosswords: reinterpretation of visual/spatial elements

Although many cryptic crossword clues rely heavily on punning misdirection, many also employ clue mechanisms which indicate that letters or letter blocks must be transposed, reversed, removed, substituted, extracted from a sequence or read as an acrostic (Aarons, 2015). In these clues, the elements providing the wordplay fodder must be decontextualized from the natural surface reading, either abandoning meaning altogether, or taking on new meaning of their own. Once these problem-

irrelevant 'chunks' have been decomposed (Knoblich, et al., 1999) the components are redeployed in quasi-algebraic fashion to form new units answering to the clue definition (Friedlander & Fine, 2016): see further Box 1.

One clue type of this nature is the 'charade': a type of riddle in which the whole word is hinted at enigmatically by reference to its component syllables (Chambers, 2014). In this process, cryptic crosswords may not observe morphological rules: for example, the word '*discourage*' would be segmented linguistically as '*dis-courage'*, but in a cryptic crossword might be clued, as '*Di (girl's name) + scour + age*' (Aarons, 2015). See further clues 1(a) and 4(f) in Boxes 1 and 4.

<INSERT BOX 3 SOMEWHERE HERE>

Similarly, rebus puzzles rely on the manipulation of words and word fragments to suggest common phrases which fit the clues displayed in a 'word-picture'. Common rebus types involve charades, the interpretation of the spatial locations of words in relation to each other, typographical trends (letter size growing, decreasing), font size or color (capitalization etc.), numbers, and letters as words (MacGregor & Cunningham, 2008; Salvi, Costantini, et al., 2016): see examples in Box 3. Rebus puzzles are also examples of ill-defined problems (Salvi, Costantini, et al., 2016): the mechanisms for achieving the problem solution are unclear to the solver, who may have to try multiple strategies before hitting upon a productive approach. As with cryptic crosswords, the solver has to relax the ingrained rules of reading in order to overcome their tacit understanding of word-form and contextual interpretation and to achieve a restructuring of the problem space (Salvi, Costantini, et al., 2016). For this reason, they are likely to trigger the insight experience (MacGregor & Cunningham, 2008; Salvi, Costantini, et al., 2016).

Rebus puzzles typically rely on the literal and quirky interpretation of encrypted elements and their spatial arrangement, which are interpreted as part of the solution (MacGregor & Cunningham, 2008). In the British TV programme '*Catchphrase*', which was based upon the solving of pictorially displayed rebus-type puzzles, the host, Roy Walker, used the tag line "Say what you see" in order to prompt contestants to find the solution (Wikipedia, 2017b). This is precisely the approach needed by a number of the rebus-style cryptic crossword clues in Box 4 which use highly inventive gimmicks to cryptically represent the solution word (clues 4 b-e).

<INSERT BOX 4 SOMEWHERE HERE>

Anagrams and cryptic crosswords: dechunking, pattern detection and misdirection

Anagrams have been routinely used in investigations of insight (for a review, see Ellis, Glaholt, & Reingold, 2011) - both for anagram solving (e.g. Novick & Sherman, 2003; Kounios, et al., 2008; Salvi, Bricolo, et al., 2016) and through the use of a paradigm requiring a simple judgment as to whether the anagram was solvable or not, in order to explore 'feelings of warmth' and solution speed (e.g. Novick & Sherman, 2003; Topolinski & Reber, 2010b).

Studies of anagram solution have consistently reported that solvers approach anagram problems using two different strategies (e.g. Novick & Sherman, 2003; Kounios, et al., 2008; Ellis, et al., 2011; Salvi, Bricolo, et al., 2016): a search methodology, using a process of serially testing out and rejecting solutions based on morphemically probable letter combinations; and 'pop-out' solutions (Novick & Sherman, 2003) whereby the solution bursts suddenly into consciousness without apparent work, often almost instantaneously. EEG research has demonstrated that self-reports distinguishing between 'pop-out' and search anagram solving are reliably accurate (Kounios, et al., 2008); this study also provides evidence that individual differences determine the solver's preferred strategy, and that different patterns of brain activity are associated with the two approaches.

It is well-established that structural features of the letter stimuli which are to be anagrammed (such as whether they are pronounceable, or form a real word in their own right) affect the difficulty and solution times of the puzzle. Thus, ZELBA or OARLY should be more difficult to resolve than HNWEI or AOSLR; and HEART should be more difficult to unscramble than THREA (Dominowski, 1969; Novick & Sherman, 2008; Ellis & Reingold, 2014; for a review see Topolinski, Bakhtiari, & Erle, 2016). Dominowski suggests that the pronounceability of the letters leads solvers to deal with them as a unit rather than as a letter-sequence (Dominowski, 1969): in other words, that familiarity with the letter patterns sets up an obstacle to solution by accessing automatically stored 'chunks' of data which will be inappropriate to the solution (cf. Knoblich, et al., 1999). It is the decomposing of these chunks into component letters which paves the way to the solution.

Anagram clues are a staple of cryptic crosswords (Upadhyay, 2008b; Aarons, 2015 p.371), being formed of the letters to be anagrammed (the 'fodder'), an anagram indicator and the definition of the resulting word (see Box 5). The letter fodder is typically concealed in misleading word units, which will be unhelpful to the anagram solution as indicated above; for this reason, many solvers will write out the letter-fodder in a random arrangement (such as a circle), in order to try to break up the

prior associations and allow new patterns to form (Johnstone, 2001 - see Box 5). However, difficulty can also be heightened by misdirection in the surface reading and by heavy disguise of the anagram indicator.

Remote Association Puzzles and Cryptic Crosswords: Spreading Activation

The Remote Associates Test (RAT), originally developed as a test of creativity (Mednick, 1962), has been refined and updated on a number of occasions, resulting in several sets of test materials (Functional Remote Associates Test (FRAT) Worthen & Clark, 1971; Compound Remote Associates (CRA) Bowden & Jung-Beeman, 2003b), and has been translated into a number of languages (Salvi, Costantini, et al., 2016). The task challenge is for the participant to consider a triad of apparently unconnected words (e.g. *Cottage, Swiss, Cake*) and to come up with a fourth word (here '*Cheese'*) which is related to all three through some type of associative connective link.

Although no longer commonly used as a test of creativity *per se* (Salvi, Costantini, et al., 2016), remote association puzzles are frequently used to study facets of creative problem-solving such as insight (Bowden, et al., 2005; MacGregor & Cunningham, 2008; Cranford & Moss, 2012; Jarosz, et al., 2012; Chein & Weisberg, 2014; Salvi, Bricolo, Franconeri, Kounios, & Beeman, 2015; Webb, et al., 2016), incubation effects (Smith & Blankenship, 1991; Cai, Mednick, Harrison, Kanady, & Mednick, 2009; Sio & Ormerod, 2015), and fixedness upon the wrong solution (Smith & Blankenship, 1989, 1991).

RAT puzzles are thought to operate through a serendipitous spreading neuronal network (Collins & Loftus, 1975) akin to three ripples, whereby each triad member simultaneously but independently activates a retrieval search of semantic memory (Smith, Sifonis, & Angello, 2012; Kenett, Anaki, & Faust, 2014; Olteţeanu & Falomir, 2015). This global search operates as a multiple constraint problem, each cue word indicating a different attribute of the target word to be satisfied; the solution is arrived at by confluence of the ripples upon a jointly shared node (Gupta, Jang, Mednick, & Huber, 2012; Smith, Huber, & Vul, 2013).

Alternatively, participants can adopt a more controlled generate-and-test strategy by considering just one of the three cues at a time, and testing out candidate solutions against each constraint for suitability, to ensure all requirements are met (Bowden & Jung-Beeman, 2007; Smith, et al., 2013). This type of analytic, step-wise process is associated with lower insight ratings and different patterns of neural activity and eye movements when compared to sudden, non-methodical solutions

(Bowden & Jung-Beeman, 2003a; Bowden & Jung-Beeman, 2007; Subramaniam, Kounios, Parrish, & Jung-Beeman, 2009; Cranford & Moss, 2012; Salvi, Costantini, et al., 2016; Webb, et al., 2016).

Impasse in solving RAT puzzles can arise from a fixation upon incorrect words, particularly those which are closely associated, syntactically or semantically, with one or more of the target words, and which therefore spring easily to mind (Harkins, 2006; Gupta, et al., 2012). This blocks access to more remotely associated words needed for the solution (Gupta, et al., 2012). Indeed, fixation in RAT problem-solving can be deliberately induced by priming commonplace associations which are unhelpful to the correct solution of the problem (Smith & Blankenship, 1991).

Consequently, one factor leading to higher performance on RAT puzzles is the ability to avoid a bias towards high-frequency candidate answers, thus allowing more remotely associated possibilities to be accessed (Gupta, et al., 2012). This accords well with Mednick's conceptualization of an uncreative person as one who possesses a 'steep associative hierarchy' containing an initially high number of stereotypical responses which rapidly tail off. By contrast, the highly creative individual will possess a 'flat associative hierarchy' containing many more items, and fewer stereotypical responses (Mednick, 1962 p.223). Creative individuals are thus argued to possess more associative links, leading to a more complex and less rigid lexical network (Gruszka & Necka, 2002; Kenett, et al., 2014).

In general terms, RAT puzzles pose a similar challenge to the 'definition' in cryptic crosswords, which may reference the target word with considerable concealment. In many cases, the sense required will not be the dominant association, but a secondary meaning (sometimes quite obscure) which will come much less readily to mind, and fixation upon the wrong sense is often deliberately induced by contextual means (Cleary, 1996 - see Box 1(c)). Breaking free from the stereotypical interpretation in order to consider a range of potentially remote synonym options is therefore key to lighting upon the correct solution (cf. Dominowski, 1995).

Even closer to the format of the RAT puzzle, however, is the 'double definition' clue (Biddlecombe, 2009; Connor, 2011a; Aarons, 2015), whereby the solver is presented with two words, both of which can be defined by the same polysemic or homographic solution word (Aarons, 2015; Pham, 2016). Occasionally, triad cryptic definitions (or even quadruple/quintuple) are also found (Connor, 2011a - see Box 6). As in jokes, double definition clues operate through 'bisociation' and an unexpected pay-off: 'the fun of seeing two disparate concepts suddenly become one' (Connor, 2011a).

<INSERT BOX 6 SOMEWHERE HERE>

Although the mechanism illustrated in Box 6 is very similar to that of RAT puzzles ('What one word links the following words?'), cryptic double definitions present extra difficulties, introducing elements of misdirection which are generally absent in RATs. First, in a dyad pairing, the two words are typically selected to form a familiar but unhelpful phrase with meaning of its own (e.g. 6(a) 'tea shop'), creating a distracting red herring (Connor, 2011a). This automatically triggered impasse must be resolved by decomposing the unhelpful 'chunked' phrase into its component features, allowing for an alternative parsing of the problem elements (Knoblich, et al., 1999). Secondly, at least one of the words is usually 'multicategorical', meaning that it can used as different parts of speech in each of the clue and the solution (Aarons, 2015). Finally, the solver must identify the 'double definition' mechanism unaided, since there is no clue-type indicator for this class (Upadhyay, 2008a). For all these reasons, double definitions can be one of the hardest clue types to crack (Connor, 2011a), requiring multiple constraining misconceptions about the meaning, form and function of the clue elements to be resolved.

Advanced Cryptic Crosswords

So far, this article has only considered cryptic clues which might appear in daily 'block-style' cryptic puzzles (Friedlander & Fine, 2016). However, a second type of cryptic crossword - advanced cryptics - also exists, which raises the difficulty still further (Friedlander & Fine, 2016). Advanced cryptic crosswords are found in weekend newspapers and some magazines, and the grids generally use bars rather than blocked grids (Friedlander & Fine, 2016). Of these, the *Listener Crossword* is the most notoriously difficult, employing a high degree of clue mechanism concealment, obscure vocabulary, grids of startling originality and a thematic challenge, often involving a number of tricky lateral thinking steps on the basis of minimal guidance (Alberich, n.d.; Listener Editorial Team, 2013). Solvers submit weekly solutions for the distinction of appearing on an annual roll of honor, but few achieve an all-correct year (Friedlander & Fine, 2016). The *Magpie*,[1] a monthly specialist magazine with five highly challenging advanced cryptic crosswords (and one mathematical puzzle) per issue, runs a similar all correct/roll of honor system, and is broadly of *Listener* standard (Friedlander & Fine, 2016).

[1] http://www.piemag.com/about/.

It is difficult to pigeon-hole the challenges set by advanced cryptics: there is an acute thirst for originality among the aficionados of these puzzles which drives setters to produce ever more creative designs, mechanisms and themes which 'require original thinking by the solver over and over again' (Anthony, 2015), and annual awards for the most admired crossword in the Magpie and Listener series are presented to setters on the basis of solver recommendation (e.g. the Listener 'Ascot Gold Cup'[2]). However, two particularly prominent sources of challenge are described below.

Thematic challenge: acquisition of incidental hints

Many advanced cryptic puzzles contain a thematic challenge, lending extra difficulty to the puzzle. In one common approach, a number of thematically related entries may have no clue, requiring the solver to deduce the answers gradually from cross-checking letters, as the grid is populated. Additionally, entire areas of the grid - such as the complete perimeter - may need to be completed with thematically relevant items or messages. In other puzzles, letter sequences spelling out thematic material may be concealed in the grid (for example on the diagonals), requiring the solver to find and highlight them through a 'wordsearch' process (Alberich, n.d.).

Thematic puzzles rely upon the solver's ability to make cross-connections between seemingly disparate items drawn from unpredictable and often obscure fields of knowledge: in this they share similarities with lateral thinking quizzes such as BBC2's *Only Connect* and BBC Radio 4's *Round Britain Quiz* (Connor, 2016). Once again, the problem space is ill-defined: the nature of the connection, the goal state and the pathway to achieve coherence are all unspecified.

In order to solve these puzzles, solvers have to accumulate incidental information along the way: hints in the title or preamble might point obliquely to the theme; suggestive word fragments might appear in the grid, and thematic material might be gradually spelled out by other means - such as corrections to misprints in the clues. The PDM comes at the instant when all the disparate pieces of information suddenly come together to make sense. It is therefore comparatively rare for the theme to be deduced from the start (indeed this element of the puzzle is often termed the 'endgame'): the solver must be able to tolerate - or even enjoy - the sensation of working for some time with unclear goals and incomplete, potentially conflicting and imprecise data. This may imply that advanced cryptic solvers tend towards personality traits such as a low 'Need for Closure' - the desire for definite knowledge and resolution of an issue (Webster & Kruglanski, 1994); and a high 'Tolerance of Ambiguity' - the perceiving of ambiguous situations as desirable, challenging and interesting

[2] http://www.listenercrossword.com/List_Awards.html

(Furnham, 1994; Zenasni, Besancon, & Lubart, 2008). Earlier research has also found that cryptic crossword solvers generally have a high 'Need for Cognition', relating to a person's tendency to seek out, engage in and enjoy effortful thinking (Friedlander & Fine, 2016; see Cacioppo, Petty, & Kao, 1984; Von Stumm & Ackerman, 2013; Furnham & Thorne, 2013).

An example of a thematic cryptic crossword challenge is shown in figure 2. Here the well-known children's song 'Old MacDonald Had a Farm' is used as a source of thematic material: "the super-familiar hiding under a thick cloak of obscurity, waiting to reward the determined solver with a PDM that feels like a surprise from an old friend" (Editorial Notes, 2013 p.10).

<Insert Figure 2 somewhere here>

Given the richness of the thematic material in this puzzle, which is expressed through multiple different devices (MacDonalds, animal noises, EIEIO title and the notation in the grid), it is likely that solvers experienced a number of PDMs - a series of mini 'insight moments' - en route to a final solution. Some PDMs would almost certainly have come out of the blue: in particular, the concealed instruction to correct the title by deleting consonants "hides in a simple statement of fact a truly surprising vowel-only "correct" title that nobody could possibly have seen coming" (Editorial Notes, 2013 p.10). The finding of the tune proved trickier:

> *"The common experience was an initial search (often for "MacDonald"), followed by some confusion, followed by careful examination of the letters in the appropriate area, followed maybe by re-reading the preamble, combined with spotting some suspect letter duplications … in other words, a penny that did drop, but did it slowly"* (Editorial Notes, 2013 p.10).

As with RAT puzzles, thematic challenges appear to operate through a ripple of spreading activation (Collins & Loftus, 1975). Each 'clue to coherence' (Bowers, Regehr, Balthazard, & Parker, 1990) embodies a different attribute of the target connection to be made; when these unconscious activations achieve confluence, the pattern emerges quite suddenly into consciousness, leading to the perception of coherence, and the PDM (a process described as 'intuitive guiding' - Bowers, et al., 1990). Individual differences will again arise in the speed, complexity and gradient of the available interassociative connections (Bowers, et al., 1990; Gruszka & Necka, 2002; Smith, et al., 2012; Kenett, et al., 2014).

Individual differences in the ability to assimilate chance hints may also be relevant: as Louis Pasteur famously remarked of his ostensibly fortuitous scientific discoveries, "Chance favors only the prepared mind" (Lecture, University of Lille, 7 December 1854 Seifert, et al., 1995). 'Opportunistic assimilation' (Seifert, et al., 1995; Sio & Ormerod, 2015) refers to the ability to absorb new and serendipitously presented information, and to allow these additional jigsaw pieces to resolve or reframe one's understanding of a problem which has previously reached impasse. Much may depend on the initial preparation stage in which the solver becomes attuned to salient or important features they have already noted (Seifert, et al., 1995; Ormerod, MacGregor, & Chronicle, 2002) which they maintain at a heightened level of activation, leading to priming effects (Sio & Ormerod, 2015). Although potentially experiencing a number of failures and false leads in the process (Ormerod, et al., 2002), progress is then made when the solver becomes intrigued by further patterns or anomalies (Kolodner & Wills, 1996), or stumbles across other relevant information (Weisberg, 2006) during completion of the grid.

The process is well-illustrated by the editorial feedback on Magpie 151/2 '*Five-a-side (on Tour)*' by Wan, which was themed around a subset of the 72 names of French scientists, engineers and mathematicians engraved on the Eiffel Tower (five from each side):

> *"In solving terms, there was a single critical, and memorable, moment of realisation when the set of names suddenly made sense. This was normally preceded by a number of less memorable moments of thinking that there was some other reason for grouping, by nationality, or by specialisation, or by university affiliation, or whatever. All the false trails had some value, because you were always going to be alert to French scientists or engineers once a few showed up. The feeling was of constant small steps forward, always with some difficulty, but never with that feeling of brick-wall despair that can accompany certain thematic endgames."* (Editorial Notes, 2015 p.9).

Individual differences in openness to experience and sensitivity to external stimuli could be relevant in these contexts, regulating the degree to which a person inhibits or remains subconsciously receptive to ostensibly incidental information (Laughlin, 1967; Simonton, 2003; Carson, Peterson, & Higgins, 2003; Weisberg, 2006; Carson, 2010; Russ & Dillon, 2011). A reduced tendency to pre-filter extraneous information as irrelevant (i.e. reduced latent inhibition) may enhance the ability to make lateral associations, and has been associated with both psychometrically and behaviorally assessed

creativity, openness to experience, and richer, more diverse associative networks (Simonton, 2003; Carson, 2010).

Spatial or Transformational Challenges: Reconceptualizing the layout

An additional source of difficulty in many advanced cryptic crosswords lies in the transformation of some elements. For example, some or all of the answers might need to be encoded or otherwise thematically altered before being entered in the grid. As in American-style 'variety puzzles', such as those appearing periodically in the Sunday edition of the NY Times (Wikipedia, 2017a), this might involve anagramming, reversing or curtailing entries (resulting in non-words in the grid); but more complex adjustments might also be required. For example the solver might deduce that all overlong items, such as APHID (to fit a grid space of 3) and CHINWAG (to fit 5), might need to be entered using Greek characters to replace the English names for the Greek alphabet (i.e. AΦD and XNWAG Alberich, n.d.). Or all entries might need to be encoded using a Playfair cipher, with the keyword to be deduced (Upadhyay, 2015). Once again, the problem space is ill-defined: the solver has to assimilate key hints or salient features as the puzzle progresses in order to deduce what adjustments need to be made, and may pursue a number of false leads before hitting upon the correct solution. Meanwhile, the completion of the grid is made much harder by the absence of securely confirmed cross-checking letters while the entry mechanism remains unresolved.

Further to this, some advanced cryptics require a type of restructuring in which the dimensions, layout or salient features of the grid itself are changed (see Figure 3). In these puzzles, there is a need to reconceptualize spatial assumptions involving placement and layout constraints, and to dismantle an existing array in favor of a new, radically different format. Cunningham highlights these two characteristics as strong features of classic spatially-oriented insight puzzles such as the nine-dot problem, the ten-coin triangle and the chain necklace puzzle (Cunningham, et al., 2009 - figure 1). Difficulty is also heightened in many of these classic puzzles by the need to identify and verify what the eventual solution would look like (MacGregor, Ormerod, & Chronicle, 2001; Cunningham, et al., 2009): this prevents steady progress towards a concrete and visualizable goal state (MacGregor, et al., 2001), even if the eventual solution criteria and constraints are made clear.

<Insert figure 3 somewhere here>

So, for example, in figure 3, the solver is made aware by means of a hidden message that the grid must be cut up and reassembled; but the purpose of this transformation, the eventual grid layout

and even the cutting line must all be deduced. Additional difficulty is introduced by the elliptical reference to a 'saw'; given the need to cut the grid and the zig-zag nature of the cut, the required interpretation of the term ('saw' = a maxim, saying) might not spring to mind. Without understanding this hint, the unspoken endgame (that of reconstructing a well-known phrase along the top and bottom line) cannot be interpreted correctly.

Incidental support for cryptic crossword clues as a form of insight puzzle

The paper review set out above plausibly suggests that cryptic crosswords can function as insight problems, using a variety of techniques, such as misdirection and an ill-defined problem space, to increase the likelihood of an 'Aha!' response. However, following the methodology set out in the '*Grounded Expertise Components Approach*' (GECA - Friedlander & Fine, 2016), the first step in the current research program was to secure empirically based corroboration for this *a priori* assumption.

Confirmation was therefore sought as part of an 84-item broad-based questionnaire, intended to characterize the cryptic crossword solving population across a wide number of dimensions. The full methodology for this research was set out in a previous publication (Friedlander & Fine, 2016). In total, 805 solvers across the full range of solving ability took part, although there was some attrition towards the end of the survey. Solvers were objectively assigned to research categories on the basis of benchmarked criteria, resulting in both a 2-way (Ordinary/Expert - O/E) and a 3-way (Ordinary/High ability/Super-Expert - O/H/S) categorization of participant expertise. For full details of the categorization rationale, see Friedlander & Fine (2016).

One key hypothesis of the survey was that "cryptic crossword solving regularly generates "Aha!" or insight moments, supporting the hypothesis that the cryptic clue is a type of insight problem through misdirection; and that this pleasurable experience is a salient driver of cryptic crossword participation" (Friedlander & Fine, 2016, p.7). To this end, the survey included a number of questions pertinent to the current discussion: results are presented below. All chi-square analyses are bootstrapped and 95% confidence intervals are reported in square brackets.

Evidence for the 'Penny-Dropping Moment' (PDM) and Incubation effects

PDM as a motivating experience

Participants were asked to rate 26 statements relating to their motivation for solving cryptic crosswords on a 5-point Likert scale (1= 'Completely Disagree'; 5= 'Completely Agree'). There were

786 responses (O: n=388; H: n=221; S: n=177). Table 1(A) shows the five highest responses to these 26 statements (with abbreviated descriptions). As previously reported (Friedlander & Fine, 2016) all groups rated the 'Aha!' moment (PDM) as a key motivational factor for solving cryptics; closely allied with this was the statement 'Solving well-written clues gives me a buzz - it makes me smile or laugh out loud' which was ranked 4th in importance. The feeling of fulfilment - whether with the completed grid or with the 'uniquely satisfying' cryptic crossword puzzle format - was also ranked highly (2nd and 5th most important). There were no statistically significant differences between the expertise groups for any of these statements. This suggests that - as for jokes - an important part of the crossword puzzle-solving experience lies in the pleasurable emotional reward bound up with the resolution of incongruity at the moment of insight. Studies of jokes and humor have found that laughter is associated with the release of endorphins which may be important in this context: the opiate effects of endorphins create a sense of wellbeing, pleasure and a sense of satisfaction (Dunbar, et al., 2011). By contrast, extrinsic motivators, such as prizes, competitions or public acclaim, were not important to participants across the board (Friedlander & Fine, 2016).

<Table 1 is inserted somewhere here>

Incubation effect

In a separate series of questions intended to capture the solving preferences of participants, respondents were invited to rate statements on a 3-way Likert scale ('No/Never'-'Perhaps/Sometimes'- 'Yes/Always'; together with a null response option 'Don't know/Not applicable'). 796 responses were made (O: 395; H: 223; S:178). Results are given in Table 1(B): figures represent the summed percentage of "Sometimes" and "Always" responses unless otherwise indicated.

Nearly 95% of solvers (94.6%; O: 95.7%; H: 95.5%; S: 91.1%) confirmed that 'incubation effects' - setting the crossword aside for a while, in order to resolve periods of impasse - were a feature of the solving process. Indeed, 80.3% of participants agreed with the full 'Yes' option: "*Yes - the answer is often obvious when I return to the crossword"* with a further 14.3% agreeing that "*I sometimes find it helpful to take a break, but I often return to the thoughts I was having previously"*. S solvers were least likely to have taken advantage of incubation breaks; even so, differences in the distribution of incubation effect between groups failed to reach statistical significance ($\chi^2(4) = 8.681$, $p = .070$, Cramer's V=.074 [.040, .135]).

Conversely, S participants were most likely (84.8%) to have found that solutions occurred to them at least occasionally when they were engaged in totally unrelated activities (e.g. shopping, driving, taking a bath). Overall 79.8% of participants agreed with this statement (O: 77.4%; H: 79.9%; S: 84.8%), but differences between the groups again failed to reach statistical significance ($\chi^2(4) = 5.393$, $p = .249$, Cramer's V=.058 [.032, .115]).

Impasse and the 'Aha' moment

Most participants also agreed that their enjoyment of the PDM was enhanced if they had needed to struggle with a clue (79.6%; O: 83.8%; H: 78.0%; S: 72.5%) although some respondents claimed that the 'Aha!' moment was unaffected by the effort expended (16.3%; O:13.7%; H: 17.0%; S: 21.3%). Very few participants claimed either that it decreased with effort expended (2.6%) or that they had never experienced a PDM (1.4%) when solving cryptics. Differences between groups approached, but did not achieve statistical significance ($\chi^2(6) = 11.796$, $p = .067$, Cramer's V=.086 [.059, .153]) and inspection of standardized residuals indicated that this was driven by the higher number of S solvers in the 'Makes no difference' group ($z = 1.7$).

Differences in solving approach between cryptic crossword expertise groups

Participants were also asked about their approach to solving cryptics in order to explore potential differences between the expertise groups; Table 2 highlights a number of key findings.

<insert Table 2 somewhere here>

Suppression of the misleading surface reading

Survey participants were asked to indicate whether they noticed the surface reading of a clue first, or read it purely as code. Two response options ('I always read the surface meaning first', 'I tend to read the surface first') favored the surface reading; two options indicated that deliberate attempts were made to exclude 'reading for sense' ('I try to exclude the misleading context', 'I always read as code: the surface meaning could be gobbledygook'); and there was one mid-way option ('Bit of both; not sure which predominates'). 797 responses were made (O: n=395; H: n=223; S: n=179); summarized details (Surface/Bit of Both/Code) are given in Table 2(A).

Most solvers (45.4%; O: 50.4%; H: 42.6%; S: 38.0%) selected the mid-way point, though this decreased with expertise; S solvers were most likely to suppress 'reading for sense' in favor of 'reading for code' (36.3%); the opposite was true for O solvers, who tended to read much more for sense (33.2%). Differences between the groups were highly significant ($\chi2(4) = 33.21$, $p < .001$, Cramer's V=.144 [.105, .199]) and inspection of standardized residuals indicated that this was driven

by higher levels of H (31.8%, z=2.0, p <.05) and S (36.3%, z=3.0, p <.01) solvers who suppressed the surface reading; and lower levels of O solvers who did this (16.5%, z= -3.5, p <.001).

Personal preferences leading to greater enjoyment of Advanced Cryptic crosswords

Solvers were asked to identify whether they solved Advanced Cryptic crosswords, and, if so, whether the quality of the clueing or the tricky endgame (or a bit of both) was their primary source of enjoyment (Table 2(B)). A small proportion of both expert groups chose not to solve Advanced Cryptic crosswords, although this was higher for H solvers than for S ('I don't do Advanced Cryptics': 8.0%; H 12.1%; S 2.8%). O solvers, by definition, do not solve this type of crossword (Friedlander & Fine, 2016, p.8) and were omitted from this analysis. Where a preference was indicated, for H solvers the quality of the clueing was paramount (27.4%; H 35.9%; S 16.8%) whereas, for a larger number of S solvers, the lateral-thinking endgame was the most important attraction (20.9%; H 13.5%; S 30.2%). Differences between the groups were highly significant ($\chi2(3)=40.47$, p< .001, Cramer's V=.317 [.226, .407]) and inspection of standardized residuals indicated that this was driven by higher levels of H (12.1%, z=2.2, p <.05) and lower levels of S (2.8%, z=-2.5, p <.05) who failed to tackle Advanced Cryptics; higher levels of H (35.9%, z=2.4, p <.05) and lower levels of S (16.8%, z=-2.7, p <.01) whose main target for enjoyment was the smooth clueing; and higher levels of S (30.2%, z=2.7, p <.01) and lower levels of H (13.5%, z=-2.4, p <.05) whose primary focus was the endgame.

Speed-solving and challenge

Solvers were also asked whether they would be disappointed if they solved a crossword rapidly (Table 2(C)). Although chi-square showed a significant association overall ($\chi2(4)$ =9.99, p= .041, Cramer's V=.079 [.050, .139]), inspection of the standardized residuals revealed no stand-out elements. As expected, S solvers (among whom were a number of competition-focused 'Speed Solvers' - see Friedlander & Fine, 2009) would be least troubled by a rapid solve ('No: I enjoy speed-solving': 12.7%; O 9.9%, z=-1.6; H 14.3%, z=0.7; S 16.9%, z=1.6), but, even for this group, numbers were low, and standardized residuals were non-significant. Nearly half the solvers indicated that they would be disappointed without a good challenge to wrestle with, and although there was some variation across the expertise groups (48.0%; O 48.4%, z=0.1; H 52.0%, z=0.9; S 42.1%, z=-1.1) inspection of the standardized residuals were once again non-significant.

Indeed, when asked whether they might switch newspapers if the crossword challenge became routinely easy (Table 2(D)), nearly 70% of solvers indicated that they would consider this (69.7%; O 70.1%; H 71.7%; S 66.3%), with differences between the groups being statistically non-significant.

Potential contribution of cryptic crosswords to insight research

The above review suggests that the cryptic crossword domain could prove a useful addition to the repository of insight problem paradigms. That they are capable of triggering insight on a regular basis is quite clear: survey results reported above indicate that cryptic crossword solvers were primarily motivated to solve cryptics because of the 'Aha!' or 'Penny-Drop' moment, and also reported that the 'laugh-out-loud' moment at the point of solving the clues was highly enjoyable. Furthermore, the detailed review of cryptic clues set out above demonstrates that they use a broad variety of insight-triggering mechanisms shared in common with a wide range of other insight problem formats. A single cryptic crossword puzzle thus presents a unique compendium of heterogeneous challenges which sets it apart from all other methodologies currently available; and this should facilitate the comparison of outcomes between device types within the crossword itself, as well as with other insight puzzle challenges external to the crossword.

One small caveat is that cryptic crosswords are primarily restricted to a number of English language speaking countries, although a few cryptic type puzzles do exist in Dutch and German. This may reduce the flexibility of cryptic crosswords as an insight puzzle paradigm. Straight-definition crosswords are, of course, available in all languages, but lack the cryptic elements described in detail in this paper which set this puzzle form apart and trigger the insight moment.

Cryptic crossword clues thus reliably trigger insight experiences, but (as for all insight puzzles) this is not exclusively the case. In cryptic crossword trials filmed for transcription using Verbal Protocol Analysis (VPA), casual inspection of the recordings suggests that not every clue produces as many PDMs; and not every solver follows the same path to solution. Systematic analysis of the video recordings (on which see further Friedlander & Fine, 2016) will allow us to take full advantage of the think-aloud protocol to capture a wide range of strategically important factors such as intuitive vs. analytical approaches to clue solution; the length of time spent in impasse on each clue before moving onto another; the frequency of return to an obstinately resistant item; perseveration with an incorrect solution pathway; the antecedents of "Aha!" solution moments; the use of cross-checking letters as opportunistic solution prompts; the suppression of the surface meaning on initial reading; the certainty of correctness (without double-checking) on solution; and the use of jottings such as candidate anagram letters (see Box 5 above) to facilitate solution (on the use of VPA in the GECA methodological approach, see further Friedlander & Fine, 2016). These aspects are all highly relevant to the discussion of insight problem solving across a wide range of problem domains.

As a precursor to the analysis, the clues used in the crossword trials will be individually analyzed to identify salient features, such as the mechanisms employed, the level and number of the constraints preventing solution, and the predicted difficulty which flows from this (following e.g. Knoblich, et al., 1999; MacGregor & Cunningham, 2009; Cunningham, et al., 2009). It is very possible that the clues vary in difficulty on a principled basis, and if so, this might lead to a better understanding of what makes a cryptic crossword clue enjoyable, and more likely to trigger insight, to lead to impasse, or to invoke 'Immediate Insight' solutions. Given the cross-over between cryptic crossword clue types and other insight puzzles, this should shed helpful light on insight mechanisms in other areas, too.

Logistically, cryptic crosswords also offer a number of advantages over other puzzle types. In the first place, there is no lack of material: cryptic crosswords appear daily in all of the British newspapers, and widely across the world in countries with historically strong connections to Britain (e.g. Canada, Ireland, Australia, New Zealand, India, and Malta: Friedlander & Fine, 2016). It is thus entirely possible to commission a professionally composed, high-quality puzzle specifically for a research study thus guaranteeing that all participants will be naïve to the challenge. Clue solution rates are high, too: in trials involving 28 solvers (both expert and non-expert) tackling a commissioned 27-clue crossword of medium difficulty, 682 of the 756 clues (90.2%) were solved correctly within the 45 minute time limit (Fine & Friedlander, in preparation). Solving times for those who finished the entire puzzle (n=19) could be very rapid indeed (range solving times: 10m47s - 40m30s; mean solving time for finishers 23m:43s, median 22m15s) resulting in solutions occurring, on average, approximately once a minute (Fine & Friedlander, in preparation).

Fast solvers in this trial were all highly expert in the field (Fine & Friedlander, in preparation), and the survey results set out above also indicate that experts may approach the solving of cryptic clues in subtly different ways to less expert solvers of equivalent experience. What could be seen as a disadvantage for this methodology (that cryptic crossword solving is a niche activity requiring inside knowledge of and experience with the clue mechanisms) thus becomes a compelling strength: there is much that might be gained from studying expert insight puzzle solvers at work, and this is currently impossible in other insight domains (such as RAT puzzles or matchstick math) which, by necessity, always use naïve populations.

Lamenting the lack of expertise studies in the insight area, Batchelder and Alexander (2012) even suggested artificially training groups of individuals to produce 'expert' solvers of such problems, commenting that experts "might have the capacity to rapidly shift their search spaces until the type

of space that contains the solution occurs to them" (Batchelder & Alexander, 2012, p.88). However, this proposal overlooks the potential role of individual differences: MacGregor and Cunningham argue that there may be reliable variations in the ability of individual subjects to solve insight problems (2008; see also DeYoung, et al., 2008; Ovington, et al., 2016) which may undermine the ecological validity of training 'experts' from a randomly selected sample of individuals. Within the crossword field we found naturally-occurring expertise groupings - all with equivalent levels of experience over many decades in the field, but with quite different expertise outcomes (Friedlander & Fine, 2016) - and this presents a unique opportunity for exploration.

The cryptic crossword survey data set out in Tables 1 and 2 above hints at some interesting differences between the various expertise groups and their approach to solving this form of puzzle. Most intriguing of all is the possibility that experts have an enhanced capacity to resist the red-herring set for them, by electively divorcing the reading of the clue from its surface meaning ('the surface meaning could be gobbledygook'), and thus shielding the mind from the deliberate misdirection. Whether expert solvers therefore experience the full phenomenological experience of the 'Aha!' moment upon solution of the clue is thus an interesting angle for further investigation: experts claim to be equally motivated by the promise of the 'Aha!' moment (Table 1), yet, paradoxically, appear to suppress that very need for Representational Change which might have been considered fundamental to the insight experience. Experts also solve more rapidly, with speed prowess being a primary focus for some (Friedlander & Fine, 2009), and this affords an opportunity to explore rapid 'pop-out' solutions and the relevance of 'Immediate Insight' to the exploration of the 'Aha!' moment.

It is also notable that significantly more 'Super-Experts' engage in Advanced Cryptic puzzles than either High Expert or Ordinary solvers, and that their primary focus in doing so is significantly more often linked, not with the appreciation of the smooth misdirection of the clueing itself, but with the complexity, novelty and lateral thinking challenge of the Advanced Cryptic endgame, which is more akin to the 'classic' insight puzzle format in its use of thematic or spatial features. This again affords opportunities to examine the multi-dimensional nature of the demands posed by different insight problem types, as described in the body of this article, and the interplay with individual differences shown by problem solvers, in terms of their thinking and personality styles.

Conclusion

In sum, this preliminary review suggests that cryptic crossword puzzles may be a promising source of insight problems offering a number of potential advantages over some of the puzzles and riddles previously used: for example, they are readily obtainable in potentially unlimited supply, solvable within acceptable time limits and suited to the simultaneous exploration of a variety of puzzle types and their potentially distinct solving mechanisms. Uniquely among existing paradigms, they also afford us the opportunity to study insight-solving expertise in action and to identify the characteristics and methodological approaches of those with a particular propensity to solve these puzzles effectively. There is therefore much to explore, and the discussion above suggests a number of particularly interesting avenues which we are currently pursuing. We believe that this new paradigm may prove to be a useful source of theoretically and empirically grounded, heterogeneous insight challenges; and that it is well-placed to shed a unique light on the workings of this elusive and intriguing aspect of human cognition.

Table 1: Responses by expertise category to questions about 'insight' properties of crossword clues

	O	H	S	All Groups
(A) Top responses to 'Crossword Motivation' question (Mean scores, out of 5)				
Number of responses to question	*388*	*221*	*177*	*786*
1. Enjoy "Penny-Drop Moment"	3.92	3.92	4.07	3.96
2. Cryptics are uniquely satisfying	3.89	4.05	3.91	3.94
3. Mental exercise to keep brain sharp	3.88	3.83	3.85	3.86
4. Makes me smile or laugh	3.79	3.80	3.64	3.76
5. Satisfaction of filled grid	3.46	3.61	3.36	3.48
(B) % Participants agreeing to the following statements				
Number of responses to question	*395*	*223*	*178*	*796*
'Setting the crossword aside for a while helps'[a]	95.7	95.5	91.1	94.6
- 'sometimes, though not always'	12.4	15.7	16.8	14.3
- 'always (answer is obvious on return)'	83.3	79.8	74.3	80.3
'I have solved clues when I'm doing something else'	77.5	79.8	84.8	79.8
'The Aha! feeling is most intense after a long struggle'				
- 'Yes'	83.8	78.0	72.5	79.6
- 'No difference one way or the other'	13.7	17.0	21.3	16.3

[a] There were 797 responses to this question; S n=179

Table 2: Differences in approach to solving cryptics

	O	H	S	All Groups
Number of responses	*395*	*223*	*179*	*797*
(A) Do you notice the surface reading or the codes of a clue first?				
- Surface first	33.2	25.6	25.7	29.4
- Bit of both: surface and codes	50.4	42.6	38.0	45.4
- Read as code, not for meaning	16.5***	31.8*	36.3**	25.2
(B) What do you look for in an Advanced Cryptic crossword?[a]				
- I don't do Advanced Cryptics	n/a	12.1*	2.8*	8.0
- Great clues	n/a	35.9*	16.8**	27.4
- Good balance of clues and endgame	n/a	38.6	50.3	43.8
- Tricky and satisfying Endgame	n/a	13.5*	30.2**	20.9
(C) Are you disappointed if you solve a crossword rapidly?[b]				
- No: I enjoy rapid solving	9.9	14.3	16.9	12.7
- Don't mind either way	41.8	33.6	41.0	39.3
- Yes: I like to wrestle with the clues	48.4	52.0	42.1	48.0

(D) I would change my crossword if the challenge got too easy ('Yes')	70.1	71.7	66.3	69.7

(*/**/*** indicates significance at the .05/.01/.001 level).
[a] Ordinary solvers, by definition, do not solve Advanced Cryptic crosswords. %s relate to 402 participants (H=223; S=179).
[b] There were 796 responses to this question; S n=178

Boxes

BOX 1 | Illustration of cryptic clue mechanisms: misleading surface readings

Clue 1(a) Active women iron some skirts and shirts (9) - (Schulman, 1996 p.309)

The definition is 'Active women' = an obliquely phrased straight definition for FEMINISTS

The wordplay comprises: FE (iron, chemical symbol) + MINIS (plural form of a type of skirt, hence the word 'some') + TS (= plural of 'T', an abbreviation for 'T-Shirt')

The surface meaning is highly misleading; additionally, the interpretation of IRON relies on a linguistic ambiguity (homonym employing different part of speech - noun, not verb).

Clue 1(b) Grown-up kid starts to gossip on aunt's Twitter (4)

The definition is 'Grown-up kid' = a misleading circumlocution for GOAT

The wordplay plays on the word 'starts' (in the nounal sense of 'leading letters', not verbal sense of 'begins') as an acrostic indicator: 'Gossip On Aunt's Twitter'.

Clue 1(c) Scrub the cooker top and clean out (6) - (Cleary, 1996, from the Guardian, No. 20248, 26 Jan 1995)

The definition is 'Scrub' = CANCEL, a non-prototypical interpretation.

The wordplay is a complex anagram of 'C' (= 'the cooker top' i.e. its initial letter) + CLEAN. The anagram indicator is the word 'OUT'.

An important secondary function of the wordplay is to guide the solver away from the required definition of the target word, and to strongly promote the more prototypical sense 'Scrub = Clean' by contextual means (Cleary, 1996).

Wordplay elements (Friedlander & Fine, 2016)

The algebraic/programming nature of the cryptic clue means that wordplay components may be flexibly recombined or anagrammed to form new units, e.g.:

- A+B = C (FAT+HER = FATHER)
- rev(A) = B (TRAMS -> SMART)
- anag(A+B) = C (CAT+HAT = ATTACH)
- trunc(A) = B (CUTTER -> UTTER)

Clues usually contain an 'indicator' identifying what type of transformation is required (Biddlecombe, 2009), but equally might be of a punning/novelty type (usually indicated by a question mark at the end of the clue).

1021
1022

BOX 2 | Illustration of cryptic clue mechanisms: jokes and puns

Clue 2(a) Frightened to death? (6,5) - (Cleary, 1996)

Answer = SCARED STIFF, with a punning reference to 'STIFF' = 'corpse', confirming the correctness of the solution.

Clue 2(b) Discovered why electrical equipment was dangerous? (9) - (Collingridge, 2010)

Answer = UNEARTHED (the latent secondary sense relates to electrical wiring)

Clue 2(c) Yorkshire beauty queen, we hear, pulls the wool over one's eyes (8) ('Orlando', in Connor, 2011b)

Answer = MISLEADS. The pun ('Miss Leeds') is indicated by a homophone indicator 'we hear', common in joke-style clues.

Clue 2(d) A wicked thing? (6) - (Aarons, 2015)

Answer = CANDLE. The clue relies on the two different homographic senses of the word 'wicked'. Difficulty is heightened by the distinctly different pronunciation (/wik'id/ ; /wikt/) and by the non-prototypical sense of 'wicked' which is required (= 'possessing a wick'). As in most punning or riddle-style clues, the quirky or nonsensical nature of the answer is flagged by the use of a question mark, which serves as a clue-type indicator.

1023
1024

BOX 3 | Rebus puzzles

3(a) poPPd (MacGregor & Cunningham, 2008)

Solution: 'Two peas in a pod": auditory pun on 'P' = 'pea', together with spatial location of the letters inside the word 'pod'.

3(b) TIMING TIM ING (Smith & Blankenship, 1989)

Solution: 'Split second timing': the second instance of 'timing' is split into two parts.

3(c) M CE /M CE /M CE (Salvi, Costantini, et al., 2016)

Solution: 'Three Blind Mice': the mice have no 'I's (eyes)

3(d) R. P. I. (MacGregor & Cunningham, 2009)

Solution: 'A grave error' (it should have been written as R.I.P.)

1025
1026
1027

BOX 4 | Illustration of cryptic clue mechanisms: rebus-like components

Clue 4(a): Player with only one leg? (4) (Guardian Crossword No. 25351, by Tramp; 17 June 2011)
Answer = IPOD, a type of music player.

The clue works by comic analogy to 'TRIPOD', with the letter 'I' standing in for the numeral 'one'. This is very similar to the rebus puzzle at Box 3(a).

Clue 4(b): Must've? (5,7,2,3,3) (Guardian Crossword No. 25351, by Tramp; 17 June 2011)
Answer = THINK OUTSIDE OF THE BOX.
Wordplay: MUSE [think] outside of TV ['the box'] - a rebus-like construction, also telling the solver what he must literally do to solve the clue. The punctuation is a highly distracting feature.

Clue 4(c): Part of it 'it an iceberg (7) - (Moorey, 2009)
Answer = TITANIC.
Wordplay: substring(A+B+C+D) leading to a hidden word, indicated by the instruction 'Part of'. The Titanic did indeed hit an iceberg, making this an '&Lit' (or 'all-in-one') clue: the clue as a whole functions as both the definition and the wordplay (Manley, 2014; Aarons, 2015).

Clue 4(d): GEGS (9,4) - (A well-known but unattributed clue, see Aarons, 2015)
Answer = SCRAMBLED EGGS. There is no guidance in the clue: the solver must literally 'say what they see'. Compare the rebus examples 3(b) and 3(c) in Box 3 above.

Clue 4(e): H,I,J,K,L,M,N,O (5) - (Another old chestnut of uncertain provenance, see Aarons, 2015)
Answer = WATER. Wordplay: "H to O", if spoken aloud, sounds like H_2O.

Clue 4(f): Somewhat swollen condition of female diving bird? (9) - Times 24451, Feb 3rd 2010
Answer = PUFFINESS = 'Somewhat swollen condition'
Wordplay = a quirky charade of PUFFIN + '-ESS' suffix, often indicative of a female in an animal species (e.g. 'lioness').

BOX 5 | Cryptic Crosswords - Anagram clues

5(a) Tube taken to theatre for three-act play (8) (Aarons, 2015 p.371)
ANSWER = CATHETER (='Tube taken to theatre').
Letter fodder = THREE-ACT; anagram indicator = 'PLAY'.
There is heavy misdirection drawing the solver away from the required medical context and into theatrical performance and the 'London Underground' (the 'Tube').

5(b) Doctor Watson's kit - or bits of modern office furniture (12)(Biddlecombe, 2009)
ANSWER = WORKSTATIONS ('bits of modern office furniture')
Letter fodder = WATSON'S KIT OR; anagram-indicator = 'Doctor'
Misleading disguise of anagram indicator in the name 'Doctor Watson', making the parsing of the clue unclear.

5(c) Find rare new frequencies beyond the visible range (8) (Johnstone, 2001, p.70)
ANSWER = INFRARED ('frequencies beyond the visible range')
Letter fodder = FIND RARE; anagram indicator = NEW
Johnstone points out that solvers often write out candidate letters as shown below, in order to facilitate the solving process:

BOX 6 | Illustration of cryptic 'double definition' clues: RAT-like mechanism

Clue 6(a): Tea shop (5) (Biddlecombe, 2009, attributed to Azed)
Answer = GRASS.
Synonym 1: 'Tea' = slang for 'marijuana' = GRASS
Synonym 2: 'Shop' = slang for 'betray to the police' = GRASS. 'Shop' has to be taken as a verb in this meaning, in contrast to the nounal function in the clue itself.

Clue 6(b): Savings book (7) (Aarons, 2015, p.365)
Answer = RESERVE.
Synonym 1: 'Savings' = a RESERVE of money
Synonym 2: 'book' = to RESERVE (a table etc.): again verbal (solution) rather than nounal (clue)

Clue 6(c): Quits flat (4) (Connor, 2011a, by Rufus)
Answer = EVEN
Synonym 1: 'Quits' = 'neither owing, nor owed' = EVEN: adjective, not verb
Synonym 2: 'Flat' = 'level' = EVEN: adjective, not noun

Clue 6(d): Left red wine in harbour (4).(Biddlecombe, 2009; Aarons, 2015 p.366)
Answer = PORT, a triple-definition
Synonym 1: 'Left' = 'on PORT side': adjective, not verb
Synonym 2: 'Red wine' = fortified PORT wine
Synonym 3: 'Harbour' = PORT

Clue 6(e) Soldier even fixed uniform (7) - Daily Telegraph 28392
Answer = REGULAR, a quadruple definition with a misleading military surface reading
Synonym 1: 'Soldier' = REGULAR (i.e. member of permanent forces)
Synonym 2: 'even' = 'level' = REGULAR (adjective, not adverb)
Synonym 3: 'fixed' = 'at set intervals' = REGULAR (adjective, not verb)
Synonym 4: 'uniform' = 'unvarying' = REGULAR (adjective, not noun)

References

Aarons, D. L. (2012). *Jokes and the Linguistic Mind*. London: Routledge.

Aarons, D. L. (2015). Following Orders: Playing Fast and Loose with Language and Letters. *Australian Journal of Linguistics, 35*(4), 351-380. doi: 10.1080/07268602.2015.1068459

Alberich. (n.d.). The Listener Crossword. *Free Crosswords Online*. [Website] Retrieved from http://www.alberichcrosswords.com/pages/listener.html

Amir, O., Biederman, I., Wang, Z., & Xu, X. (2015). Ha Ha! Versus Aha! A direct comparison of humor to nonhumorous insight for determining the neural correlates of mirth. *Cerebral Cortex, 25*(5), 1405-1413. doi: 10.1093/cercor/bht343

Ansburg, P. I., & Dominowski, R. L. (2000). Promoting insightful problem solving. *The Journal of Creative Behavior, 34*(1), 30-60.

Anthony, S. (2015, April). Editorial. *The Magpie (Cryptic Crossword Magazine),*Vol. 13(4)*,* Issue No. 148, S. Anthony, M. Goodliffe & S. Shabankareh (Eds.), Lewes, East Sussex. Retrieved from www.piemag.com.

Ash, I. K., Cushen, P. J., & Wiley, J. (2009). Obstacles in investigating the role of restructuring in insightful problem solving. *The Journal of Problem Solving, 2*(2), 3.

Ash, I. K., Jee, B. D., & Wiley, J. (2012). Investigating insight as sudden learning. *The Journal of Problem Solving, 4*(2), 2.

Attardo, S., Hempelmann, C. F., & Di Maio, S. (2002). Script oppositions and logical mechanisms: Modeling incongruities and their resolutions. *Humor, 15*(1), 3-46.

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W., Franklin, M. S., & Schooler, J. W. (2012). Inspired by distraction: mind wandering facilitates creative incubation. *Psychol Sci, 23*(10), 1117-1122. doi: 10.1177/0956797612446024

Bartolo, A., Benuzzi, F., Nocetti, L., Baraldi, P., & Nichelli, P. (2006). Humor comprehension and appreciation: an FMRI study. *Journal of Cognitive Neuroscience, 18*(11), 1789-1798.

Batchelder, W. H., & Alexander, G. E. (2012). Insight problem solving: A critical examination of the possibility of formal theory. *The Journal of Problem Solving, 5*(1), 56-100. doi: 10.7771/1932-6246.1143

Biddlecombe, P. (2009, 06/12/2011). Yet Another Guide to Cryptic Crosswords (YAGCC) - Clue Types. Retrieved from http://www.biddlecombe.demon.co.uk/yagcc/YAGCC2.html

Bowden, E. M., & Jung-Beeman, M. (2003a). Aha! Insight experience correlates with solution activation in the right hemisphere. *Psychonomic Bulletin & Review, 10*(3), 730-737.

Bowden, E. M., & Jung-Beeman, M. (2003b). Normative data for 144 compound remote associate problems. *Behavior Research Methods, Instruments, & Computers, 35*(4), 634-639.

Bowden, E. M., & Jung-Beeman, M. (2007). Methods for investigating the neural components of insight. *Methods, 42*(1), 87-99. doi: org/10.1016/j.ymeth.2006.11.007

Bowden, E. M., Jung-Beeman, M., Fleck, J., & Kounios, J. (2005). New approaches to demystifying insight *Trends in Cognitive Sciences 9*(7), 322-328 doi: 10.1016/j.tics.2005.05.012

Bowers, K. S., Regehr, G., Balthazard, C., & Parker, K. (1990). Intuition in the context of discovery. *Cognitive psychology, 22*(1), 72-110.

Cacioppo, J. T., Petty, R. E., & Kao, C. E. (1984). The efficient assessment of need for cognition. *Journal of Personality Assessment, 48*, 306-307.

Cai, D. J., Mednick, S. A., Harrison, E. M., Kanady, J. C., & Mednick, S. C. (2009). REM, not incubation, improves creativity by priming associative networks. *Proceedings of the National Academy of Sciences, 106*(25), 10130-10134.

Canestrari, C., & Bianchi, I. (2012). Perception of Contrariety in Jokes. *Discourse Processes, 49*(7), 539-564. doi: 10.1080/0163853X.2012.710524

Carson, S. H. (2010). Latent inhibition and creativity. In R. E. Lubow & I. Weiner (Eds.), *Latent inhibition: Data, theories, and applications to schizophrenia* (pp. 183-198). New York: Cambridge University Press.

Carson, S. H., Peterson, J. B., & Higgins, D. M. (2003). Decreased latent inhibition is associated with increased creative achievement in high-functioning individuals. *Journal of Personality & Social Psychology, 85*(3), 499-506.

Chalicea. (2016, October). Saw. *The Magpie (Cryptic Crossword Magazine),*Vol. 14 (10)*,* Issue No. 166, S. Anthony, M. Goodliffe & S. Shabankareh (Eds.), Lewes, East Sussex. Retrieved from www.piemag.com.

Chambers. (2014) *Chambers Dictionary* (13th ed.). London: Chambers Harrap Publishers Ltd

Chan, Y.-C. (2016). Neural Correlates of Sex/Gender Differences in Humor Processing for Different Joke Types. *Frontiers in Psychology, 7*. doi: 10.3389/fpsyg.2016.00536

Chein, J. M., & Weisberg, R. W. (2014). Working memory and insight in verbal problems: Analysis of compound remote associates. *Memory & cognition, 42*(1), 67-83.

Chronicle, E. P., MacGregor, J. N., & Ormerod, T. C. (2004). What makes an insight problem? The roles of heuristics, goal conception, and solution recoding in knowledge-lean problems. *Journal of Experimental Psychology: Learning, memory, and cognition, 30*(1), 14.

Chu, Y., & MacGregor, J. N. (2011). Human Performance on Insight Problem Solving: A Review. *The Journal of Problem Solving, 3*(2), 119-150. doi: 10.7771/1932-6246.1094

Cleary, J. (1996). Misleading Contexts: The Construction of Ambiguity in the Cryptic Crossword Clue. *Edinburgh Working Papers in Applied Linguistics, 7*, 14-29.

Collingridge, P. (2010, 16th February). Cryptic crossword clues and Christmas crackers [Blog]. *Peter's Website*. Retrieved from http://www.petercollingridge.co.uk/blog/cryptic-crossword-clues-and-christmas-crackers

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological review, 82*(6), 407.

Connor, A. (2011a, 17th November). Cryptic crosswords for beginners: Double definitions *Crossword Blog*. Retrieved from https://www.theguardian.com/crosswords/crossword-blog/2011/nov/17/cryptic-crosswords-for-beginners-double-definitions

Connor, A. (2011b, 8th December). Cryptic crosswords for beginners: Soundalikes. *Crossword Blog*. Retrieved from https://www.theguardian.com/crosswords/crossword-blog/2011/dec/08/cryptic-crosswords-for-beginners-soundalikes

Connor, A. (2014). *Two Girls, One on Each Knee (7)*. London: Penguin Books.

Connor, A. (2016). *The Joy of Quiz*. UK: Particular Books, Penguin, Random House.

Cranford, E. A., & Moss, J. (2011, July 20th-23rd). *An fMRI study of insight using compound remote associate problems.* Paper presented at the 33rd Annual Conference of the Cognitive Science Society, Austin, TX.

Cranford, E. A., & Moss, J. (2012). Is Insight Always the Same? A Protocol Analysis of Insight in Compound Remote Associate Problems. *The Journal of Problem Solving, 4*(2/Spring), 128-153.

Cunningham, J. B., MacGregor, J. N., Gibb, J., & Haar, J. (2009). Categories of insight and their correlates: An exploration of relationships among classic-type insight problems, rebus puzzles, remote associates and esoteric analogies. *Journal of Creative Behavior, 43*(4), 262-280.

Cunningham, W. A., & Derks, P. (2005). Humor appreciation and latency of comprehension. *Humor, 18*(4), 389-403. doi: 10.1515/humr.2005.18.4.389

Danek, A. H., Fraps, T., von Müller, A., Grothe, B., & Öllinger, M. (2013). Aha! experiences leave a mark: facilitated recall of insight solutions. *Psychological research, 77*(5), 659-669. doi: 10.1007/s00426-012-0454-8

Danek, A. H., Fraps, T., von Müller, A., Grothe, B., & Öllinger, M. (2014a). It's a kind of magic—what self-reports can reveal about the phenomenology of insight problem solving. *Frontiers in psychology, 5*, 1-11.

Danek, A. H., Fraps, T., Von Müller, A., Grothe, B., & Öllinger, M. (2014b). Working wonders? Investigating insight with magic tricks. *Cognition, 130*(2), 174-185. doi: 10.1016/j.cognition.2013.11.003

Danek, A. H., Wiley, J., & Öllinger, M. (2016). Solving classical insight problems without aha! experience: 9 dot, 8 coin, and matchstick arithmetic problems. *The Journal of Problem Solving, 9*(1), 47-57.

Davidson, J. E. (1995). The suddenness of insight. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 125-156). Cambridge MA: MIT Press.

Davidson, J. E. (2003). Insights about insightful problem solving. In J. E. Davidson & R. J. Sternberg (Eds.), *The psychology of problem solving* (pp. 149-175). New York: Cambridge University Press.

DeYoung, C. G., Flanders, J. L., & Peterson, J. B. (2008). Cognitive abilities involved in insight problem solving: an individual differences model. *Creativity Research Journal, 20*(3), 278-290

Dienhart, J. M. (1999). A linguistic look at riddles. *Journal of pragmatics, 31*(1), 95-125.

Dominowski, R. L. (1969). The effect of pronunciation practice on anagram difficulty. *Psychonomic Science, 16*(2), 99-100.

Dominowski, R. L. (1995). Productive problem solving. In S. M. Smith, T. B. Ward & R. A. Finke (Eds.), *The creative cognition approach* (pp. 73-95). Cambridge, MA: MIT Press.

Dominowski, R. L., & Buyer, L. S. (2000). Retention of problem solutions: the re-solution effect. *Am J Psychol, 113*(2), 249-274.

Dunbar, R. I. M., Baron, R., Frangou, A., Pearce, E., van Leeuwin, E. J. C., Stow, J., et al. (2011). Social laughter is correlated with an elevated pain threshold. *Proceedings of the Royal Society of London B: Biological Sciences*. doi: 10.1098/rspb.2011.1373

Dunbar, R. I. M., Launay, J., & Curry, O. (2016). The complexity of jokes is limited by cognitive constraints on mentalizing. *Human Nature, 27*(2), 130-140.
Editorial Notes. (2013, December). Solutions for Issue 130, October 2013. *The Magpie (Cryptic Crossword Magazine),*Vol. 11(12)*,* Issue No. 132, S. Anthony, M. Goodliffe & S. Shabankareh (Eds.), Lewes, East Sussex. Retrieved from www.piemag.com.
Editorial Notes. (2015, September). Solutions for Issue 151, July 2015. *The Magpie (Cryptic Crossword Magazine),*Vol. 13(9)*,* Issue No. 153, S. Anthony, M. Goodliffe & S. Shabankareh (Eds.), Lewes, East Sussex. Retrieved from www.piemag.com.
Ellis, J. J., Glaholt, M. G., & Reingold, E. M. (2011). Eye movements reveal solution knowledge prior to insight. *Consciousness and cognition, 20*(3), 768-776.
Ellis, J. J., & Reingold, E. M. (2014). The Einstellung effect in anagram problem solving: evidence from eye movements. *Frontiers in Psychology, 5*(679). doi: 10.3389/fpsyg.2014.00679
Erdelyi, M. H. (2014). The interpretation of dreams, and of jokes. *Review of General Psychology, 18*(2), 115-126. doi: 10.1037/gpr0000002
Evans, J. S., & Stanovich, K. E. (2013). Dual-Process Theories of Higher Cognition: Advancing the Debate. *Perspect Psychol Sci, 8*(3), 223-241. doi: 10.1177/1745691612460685
Festinger, L. (1957). *A Theory of Cognitive Dissonance*. Evanston, IL: Row Peterson.
Fine, P. A., & Friedlander, K. J. (in preparation). Cryptic crossword expertise and fluid intelligence.
Forabosco, G. (2008). Is the concept of incongruity still a useful construct for the advancement of humor research? *Lodz Papers in Pragmatics, 4*(1), 45-62.
Friedlander, K. J., & Fine, P. A. (2009, 15-18 December). *Expertise in cryptic crossword performance: An exploratory survey.* Paper presented at the Proceedings of the International Symposium on Performance Science, University of Auckland, NZ;.
Friedlander, K. J., & Fine, P. A. (2016). The Grounded Expertise Components Approach in the novel area of cryptic crossword solving. *Frontiers in Psychology, 7*. doi: 10.3389/fpsyg.2016.00567
Furnham, A. (1994). A content, correlational and factor analytic study of four tolerance of ambiguity questionnaires. *Personality and Individual Differences, 16*(3), 403-410.
Furnham, A., & Thorne, J. D. (2013). Need for cognition. *Journal of Individual Differences, 34*, 230-240. doi: 10.1027/1614-0001/a000119.
Gick, M. L., & Lockhart, R. S. (1995). Cognitive and affective components of insight. In R. J. Sternberg & J. E. Davidson (Eds.), *The Nature of Insight* (pp. 197-228). Cambridge, MA: Bradford Books/MIT Press.
Gilhooly, K. J. (2016). Incubation and Intuition in Creative Problem Solving. *Frontiers in Psychology, 7*(1076). doi: 10.3389/fpsyg.2016.01076
Gilhooly, K. J., Ball, L. J., & Macchi, L. (2015). Insight and creative thinking processes: Routine and special. *Thinking & Reasoning, 21*(1), 1-4.
Gruszka, A., & Necka, E. (2002). Priming and acceptance of close and remote associations by creative and less creative people. *Creativity Research Journal, 14*(2), 193-205.
Gupta, N., Jang, Y., Mednick, S. C., & Huber, D. E. (2012). The Road Not Taken: Creative Solutions Require Avoidance of High-Frequency Responses. *Psychological Science, 23*(3), 288-294.
Harkins, S. G. (2006). Mere effort as the mediator of the evaluation-performance relationship. *Journal of Personality and Social Psychology, 91*(3), 436-455. doi: 10.1037/0022-3514.91.3.436
Hélie, S., & Sun, R. (2010). Incubation, insight, and creative problem solving: a unified theory and a connectionist model. *Psychol Rev, 117*(3), 994-1024. doi: 10.1037/a0019532
Hill, G., & Kemp, S. M. (2016). Uh-Oh! What Have We Missed? A Qualitative Investigation into Everyday Insight Experience. *The Journal of Creative Behavior*, [Epub ahead of print]. doi: 10.1002/jocb.142
Hurley, M. M., Dennett, D. C., & Adams, R. B. (2011). *Inside jokes: Using humor to reverse-engineer the mind*: MIT press.
Ifor. (2013, October). The Title is Wrong. *The Magpie (Cryptic Crossword Magazine),*Vol. 11(10)*,* Issue No. 130.4, S. Anthony, M. Goodliffe & S. Shabankareh (Eds.), Lewes, East Sussex. Retrieved from www.piemag.com.
Jarosz, A. F., Colflesh, G. J. H., & Wiley, J. (2012). Uncorking the muse: Alcohol intoxication facilitates creative problem solving. *Consciousness and Cognition, 21*(1), 487-493.
Johnstone, A. H. (2001). Can Problem Solving Be Taught? Proceedings from the Nyholm Symposium: Are we teaching our students the skills they need? *University Chemistry Education, 5*(2), 69-73.
Jones, G. (2003). Testing two cognitive theories of insight. *Journal of Experimental Psychology: Learning, Memory and Cognition, 29*(5), 1017-1027.

Kenett, Y. N., Anaki, D., & Faust, M. (2014). Investigating the structure of semantic networks in low and high creative persons. *Front Hum Neurosci, 8*, 407. doi: 10.3389/fnhum.2014.00407

Knoblich, G., Ohlsson, S., Haider, H., & Rhenius, D. (1999). Constraint relaxation and chunk decomposition in insight problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(6), 1534-1555. doi: 10.1037/0278-7393.25.6.1534

Knoblich, G., Ohlsson, S., & Raney, G. E. (2001). An eye movement study of insight problem solving. *Memory & cognition, 29*(7), 1000-1009.

Koestler, A. (1964). *The act of creation*. London: Hutchinson.

Kolodner, J. L., & Wills, L. M. (1996). Powers of observation in creative design. *Design Studies, 17*(4), 385-416. doi: http://dx.doi.org/10.1016/S0142-694X(96)00021-X

Kounios, J., & Beeman, M. (2014). The cognitive neuroscience of insight. *Annual review of psychology, 65*, 71-93. doi: 10.1146/annurev-psych-010213-115154

Kounios, J., Fleck, J., Green, D. L., Payne, L., Stevenson, J. L., Bowden, E. M., et al. (2008). The origins of insight in resting-state brain activity. *Neuropsychologia, 46*(1), 281-291. doi: 10.1016/j.neuropsychologia.2007.07.013

Kounios, J., & Jung-Beeman, M. (2009). The Aha! Moment: The Cognitive Neuroscience of Insight. *Current Directions in Psychological Science, 18*(4), 210-216.

Kozbelt, A., & Nishioka, K. (2010). Humor comprehension, humor production, and insight: An exploratory study. *Humor - International Journal of Humor Research, 23*(3), 375-401. doi: 10.1515/humr.2010.017

Laughlin, P. R. (1967). Incidental concept formation as a function of creativity and intelligence. *Journal of personality and social psychology, 5*(1), 115-119.

Listener Editorial Team. (2013). Listener Crossword: Introduction. [Website] Retrieved from http://www.listenercrossword.com/List_Intro.html

MacGregor, J. N., & Cunningham, J. B. (2008). Rebus puzzles as insight problems. *Behavior research methods, 40*(1), 263-268.

MacGregor, J. N., & Cunningham, J. B. (2009). The effects of number and level of restructuring in insight problem solving. *The Journal of Problem Solving, 2*(2), 130-141.

MacGregor, J. N., Ormerod, T. C., & Chronicle, E. P. (2001). Information processing and insight: a process model of performance on the nine-dot and related problems. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(1), 176-201.

Manley, D. (2014). *Chambers Crossword Manual* (5th Revised ed.). London: Chambers.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychol Rev, 69*(3), 220-232.

Metcalfe, J. (1986). Feeling of knowing in memory and problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*(2), 288-294.

Moorey, T. (2009). Cryptic Crosswords: Clue Types and Indicators. [Website] Retrieved from http://www.timmoorey.info/pdfs/clue_types.pdf

Navon, D. (1988). The seemingly appropriate but virtually inappropriate: notes on characteristics of jokes. *Poetics, 17*(3), 207-219.

Novick, L. R., & Sherman, S. (2003). On the nature of insight solutions: evidence from skill differences in anagram solution. *The Quarterly Journal of Experimental Psychology, Section A, 56*(2), 351-382.

Novick, L. R., & Sherman, S. J. (2008). The effects of superficial and structural information on online problem solving for good versus poor anagram solvers. *The Quarterly Journal of Experimental Psychology, 61*(7), 1098-1120.

Ohlsson, S. (2011). *Deep learning: How the mind overrides experience*: Cambridge University Press.

Ohlsson, S., Ernst, A. M., & Rees, E. (1992). The cognitive complexity of learning and doing arithmetic. *Journal for Research in Mathematics Education*, 441-467.

Öllinger, M., Jones, G., & Knoblich, G. (2008). Investigating the effect of mental set on insight problem solving. *Experimental psychology, 55*(4), 269-282. doi: 10.1027/1618-3169.55.4.269

Öllinger, M., Jones, G., & Knoblich, G. (2014). The dynamics of search, impasse, and representational change provide a coherent explanation of difficulty in the nine-dot problem. *Psychological research, 78*(2), 266-275. doi: 10.1007/s00426-013-0494-8

Öllinger, M., & Knoblich, G. (2009). Psychological research on insight problem solving. In H. Atmanspacher & H. Primas (Eds.), *Recasting reality: Wolfgang Pauli's philosophical ideas and contemporary science* (pp. 275-300). Berlin: Springer.

Olteţeanu, A.-M., & Falomir, Z. (2015). comRAT-C: A computational compound Remote Associates Test solver based on language data and its comparison to human performance. *Pattern Recognition Letters, 67*, 81-90.

1261 Ormerod, T. C., MacGregor, J. N., & Chronicle, E. P. (2002). Dynamics and constraints in insight problem
1262 solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(4), 791-799.
1263 Ovington, L. A., Saliba, A. J., & Goldring, J. (2016). Dispositional Insight Scale: Development and Validation of a
1264 Tool That Measures Propensity Toward Insight In Problem Solving. *Creativity Research Journal, 28*(3),
1265 342-347. doi: 10.1080/10400419.2016.1195641
1266 Ovington, L. A., Saliba, A. J., Moran, C. C., Goldring, J., & MacDonald, J. B. (2015). Do people really have insights
1267 in the shower? The when, where and who of the Aha! Moment. *The Journal of Creative Behavior*,
1268 [EPub ahead of publication].
1269 Patrick, J., Ahmed, A., Smy, V., Seeby, H., & Sambrooks, K. (2015). A cognitive procedure for representation
1270 change in verbal insight problems. *Journal of Experimental Psychology: Learning, Memory, and*
1271 *Cognition, 41*(3), 746–759.
1272 Pham, T. (2016). The register of English crossword puzzles: Studies in intertextuality. In C. Schubert & C.
1273 Sanchez-Stockhammer (Eds.), *Variational Text Linguistics: Revisiting Register in English* (Vol. 90, pp.
1274 111-137). Berlin/Boston: Walter de Gruyter GmbH.
1275 Pretz, J. E., Naples, A. J., & Sternberg, R. J. (2003). Recognizing, defining and representing problems. In J. E.
1276 Davidson & R. J. Sternberg (Eds.), *The psychology of problem solving* (pp. 3-30). New York: Cambridge
1277 University Press.
1278 Ramachandran, V. S. (1998). The neurology and evolution of humor, laughter, and smiling: the false alarm
1279 theory. *Medical Hypotheses, 51*(4), 351-354. doi: http://dx.doi.org/10.1016/S0306-9877(98)90061-5
1280 Robertson, S. I. (2001). *Problem solving*. Hove: Psychology Press.
1281 Russ, R. W., & Dillon, J. A. (2011). Associative theory. In M. A. Runco & S. R. Pritzker (Eds.), *Encyclopedia of*
1282 *creativity* (2nd ed., Vol. 1, pp. 66-71). Boston, MA: Academic Press.
1283 Salvi, C., Bricolo, E., Franconeri, S. L., Kounios, J., & Beeman, M. (2015). Sudden insight is associated with
1284 shutting out visual inputs. *Psychonomic bulletin & review, 22*(6), 1814-1819.
1285 Salvi, C., Bricolo, E., Kounios, J., Bowden, E., & Beeman, M. (2016). Insight solutions are correct more often
1286 than analytic solutions. *Thinking & reasoning, 22*(4), 443-460.
1287 Salvi, C., Costantini, G., Bricolo, E., Perugini, M., & Beeman, M. (2016). Validation of Italian rebus puzzles and
1288 compound remote associate problems. *Behavior research methods, 48*(2), 664-685. doi:
1289 10.3758/s13428-015-0597-9
1290 Schulman, A. (1996). The Art of the Puzzler. In M. P. Friedman & E. C. Carterette (Eds.), *Cognitive Ecology:*
1291 *Handbook of Perception and Cognition* (2nd ed., Vol. 16, pp. 293-321). San Diego, CA: Academic Press.
1292 Seifert, C. M., Meyer, D. E., Davidson, N., Patalano, A. L., & Yaniv, I. (1995). Demystification of cognitive insight:
1293 Opportunistic assimilation and the prepared-mind hypothesis. In R. J. Sternberg & J. E. Davidson
1294 (Eds.), *The Nature of Insight* (pp. 65-124). Cambridge, MA: MIT Press.
1295 Shen, W., Yuan, Y., Liu, C., & Luo, J. (2015). In search of the 'Aha!'experience: Elucidating the emotionality of
1296 insight problem-solving. *British Journal of Psychology, 107*(2), 281-298. doi: 10.1111/bjop.12142
1297 Shen, W., Yuan, Y., Liu, C., Zhang, X., Luo, J., & Gong, Z. (2016). In creative insight task-specific? A coordinate-
1298 based meta-analysis of neuroimaging studies on insightful problem solving. *International Journal of*
1299 *Psychophysiology, 110*, 81-90. doi: http://dx.doi.org/10.1016/j.ijpsycho.2016.10.001
1300 Simon, H. A. (1973). The structure of ill structured problems. *Artificial intelligence, 4*(3-4), 181-201.
1301 Simonton, D. K. (2003). Scientific creativity as constrained stochastic behavior: The integration of product,
1302 person, and process perspectives. *Psychological Bulletin, 129*(4), 475-494. doi: 10.1037/0033-
1303 2909.129.4.475
1304 Sio, U. N., & Ormerod, T. C. (2009). Does incubation enhance problem solving? A meta-analytic review.
1305 *Psychological Bulletin, 135*, 94–120.
1306 Sio, U. N., & Ormerod, T. C. (2015). Incubation and cueing effects in problem-solving: Set aside the difficult
1307 problems but focus on the easy ones. *Thinking & Reasoning, 21*(1), 113-129.
1308 Smith, K. A., Huber, D. E., & Vul, E. (2013). Multiply-constrained semantic search in the Remote Associates
1309 Test. *Cognition, 128*(1), 64-75.
1310 Smith, S. M. (2003). The constraining effects of initial ideas. In P. B. Paulus & B. A. Nijstad (Eds.), *Group*
1311 *creativity: Innovation through collaboration* (pp. 15-31). New York, US: Oxford University Press Inc.
1312 Smith, S. M., & Blankenship, S. E. (1989). Incubation effects. *Bulletin of the Psychonomic Society, 27*(4), 311-
1313 314. doi: 10.3758/bf03334612
1314 Smith, S. M., & Blankenship, S. E. (1991). Incubation and the Persistence of Fixation in Problem Solving. *The*
1315 *American Journal of Psychology, 104*(1), 61-87.
1316 Smith, S. M., Sifonis, C. M., & Angello, G. (2012). Clue insensitivity in remote associates test problem solving.
1317 *The Journal of Problem Solving, 4*(2), 28-49. doi: 10.7771/1932-6246.1124

Sowden, P. T., Pringle, A., & Gabora, L. (2015). The shifting sands of creative thinking: Connections to dual-process theory. *Thinking & Reasoning, 21*(1), 40-60.

Subramaniam, K., Kounios, J., Parrish, T. B., & Jung-Beeman, M. (2009). A brain mechanism for facilitation of insight by positive affect. *Journal of cognitive neuroscience, 21*(3), 415-432. doi: 10.1162/jocn.2009.21057

Suls, J. M. (1972). *A two-stage model for the appreciation of jokes and cartoons: An information-processing analysis*. New York and London: Academic Press.

Topolinski, S., Bakhtiari, G., & Erle, T. M. (2016). Can I cut the Gordian tnok? The impact of pronounceability, actual solvability, and length on intuitive problem assessments of anagrams. *Cognition, 146*, 439-452.

Topolinski, S., & Reber, R. (2010a). Gaining Insight Into the "Aha" Experience. *Current Directions in Psychological Science, 19*(6), 402-405. doi: 10.1177/0963721410388803

Topolinski, S., & Reber, R. (2010b). Immediate truth–Temporal contiguity between a cognitive problem and its solution determines experienced veracity of the solution. *Cognition, 114*(1), 117-122.

Underwood, G., MacKeith, J., & Everatt, J. (1988). Individual differences in reading skill and lexical memory: the case of the crossword puzzle expert. In M. M. Gruneberg, P. E. Morris & R. N. Sykes (Eds.), *Practical aspects of memory: current research and issues* (Vol. 2: Clinical and educational implications, pp. 301-308). Chichester: Wiley.

Upadhyay, S. (2008a, 18th October). Decoding Double Definitions [Blog]. *Crossword Unclued*. Retrieved from http://www.crosswordunclued.com/2008/10/decoding-double-definitions.html

Upadhyay, S. (2008b, Aug 11th). How To Spot Anagrams [Blog]. *Crossword Unclued*. Retrieved from http://www.crosswordunclued.com/2008/08/how-to-spot-anagram.html

Upadhyay, S. (2015, July 17th). Playfair [Blog]. *Crossword Unclued*. Retrieved from http://www.crosswordunclued.com/2015/07/playfair.html

Von Stumm, S., & Ackerman, P. L. (2013). Investment and intellect: A review and meta-analysis. *Psychological bulletin, 139*(4), 841-869.

Wallas, G. (1926). *The Art of Thought*. New York: Harcourt Brace.

Webb, M. E., Little, D. R., & Cropper, S. J. (2016). Insight Is Not in the Problem: Investigating Insight in Problem Solving across Task Types. *Front Psychol, 7*, 1424. doi: 10.3389/fpsyg.2016.01424

Webster, D. M., & Kruglanski, A. W. (1994). Individual differences in need for cognitive closure. *Journal of Personality and Social Psychology, 67*(6), 1049-1062.

Weisberg, R. W. (1995). Prolegomena to theories of insight: a taxonomy of problems. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. pp. 157-196). Cambridge MA: MIT Press.

Weisberg, R. W. (2006). *Creativity: Understanding innovation in problem solving, science, invention, and the arts*: John Wiley & Sons.

Weisberg, R. W. (2015). Toward an integrated theory of insight in problem solving. *Thinking & Reasoning, 21*(1), 5-39.

Wikipedia. (2017a). The New York Times crossword puzzle. [Website] Retrieved from https://en.wikipedia.org/wiki/The_New_York_Times_crossword_puzzle 22/06/2017

Wikipedia. (2017b). Roy Walker (comedian). [Website] Retrieved from https://en.wikipedia.org/wiki/Roy_Walker_(comedian) 30/05/2017

Wiley, J. (1998). Expertise as mental set: The effects of domain knowledge in creative problem solving. *Memory & cognition, 26*(4), 716-730.

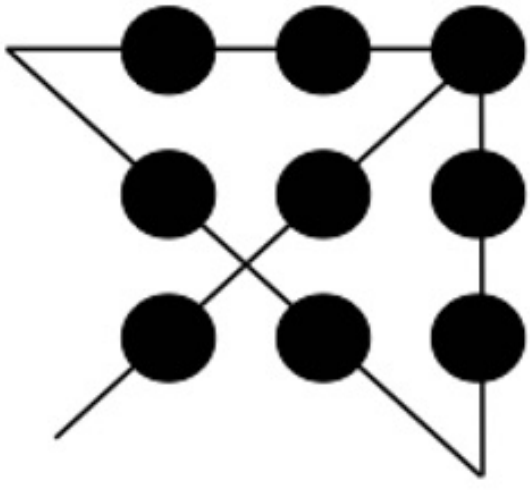
Worthen, B. R., & Clark, P. M. (1971). Toward an improved measure of remote associational ability. *Journal of Educational Measurement, 8*(2), 113-123.

Yim, J. (2016). Therapeutic Benefits of Laughter in Mental Health: A Theoretical Review. *The Tohoku Journal of Experimental Medicine, 239*(3), 243-249.

Zenasni, F., Besancon, M., & Lubart, T. (2008). Creativity and Tolerance of Ambiguity: An Empirical Study. *Journal of Creative Behavior, 42*(1), 61-73.

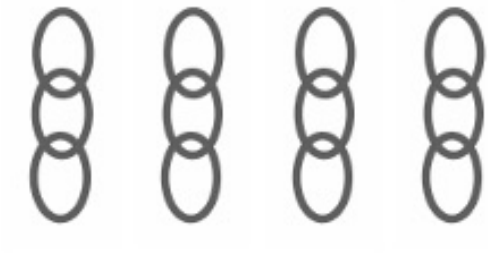
Zhao, Q., Zhou, Z., Xu, H., Chen, S., Xu, F., Fan, W., et al. (2013). Dynamic neural network of insight: A functional magnetic resonance imaging study on solving Chinese 'Chengyu'riddles. *PloS one, 8*(3), e59351.

Figure 1.JPEG



(a) The '9-dot' puzzle. The challenge is to draw through every dot once, using only four lines. The insight moment arises when the participant realises that he can draw 'outside the box'.

(b) The 10 coin triangle. By moving three coins only, the triangle must be inverted.



(c) You have four pieces of a chain necklace, which you wish to join into a single circle of 12 links. It costs $2 to open a link, and $3 to close a link. You have $15. How can you do this?

K	K	K	K
Q	Q	Q	Q
J	J	J	J

(d) Arrange the 12 cards (4 Kings, 4 Queens and 4 Jacks) from a standard deck in grid-formation so that each row and each column contains only one Jack, one Queen and one King.

Figure 1 | Classic brainteaser puzzles used to explore insight: see further Cunningham et al. (2009).

Figure 2.JPEG

The Title is Wrong

by Ifor

Answers to four clues have a thematically related connection (RAMSAY, FLORA, JEANETTE and MALCOLM - all turn out to share the surname 'MacDonald').

Four other answers are to be replaced with words, not necessarily of the same length: this resulted in the answers PIG, GOAT, SHEEP, COW being replaced by their noises (OINK, MAA, BAA, MOO) in the grid.

A third group of normal clues had entries containing one of the twelve letters which solvers had to highlight to 'denote the theme'. Careful examination of the grid enabled more astute solvers to spot the opening notes of *Old MacDonald* arranged as if on a musical stave - a gimmick based upon a punning definition of 'denoted'.

Corrections to misprints in the remaining clues spell out instructions for correcting the title: 'CLEAR ALL THE CONSONANTS'. Following this instruction modifies '*The Title is Wrong*' to 'E I E I O', the refrain from the song. This had to be written below the grid in the final submission.

Figure 2 | Magpie crossword issue 130.4 (Ifor, 2013)

Figure 3.JPEG

Saw

by Chalicea

Instructions:

The wordplay in across clues yields the answer, along with an extra letter that is not entered in the grid.

In clue order these give instructions.

Before carrying these out, solvers need to change one word in the solution grid to the word that appears symmetrically opposite it in the grid, leaving real words.

Solution:

The original grid is completed as shown above, with one word replaced: WEEKS (41a) is changed to match WORTH (4a). The extra letters spell out the instruction 'CUT IN TWO, REFORM, SHADE SAW'. The solver must deduce the cutting line (shown by red dashes above).

Cutting along the red dotted line as indicated, in a step pattern, and reassembling the two halves in the new layout produces the 'saw' (= 'saying, proverb'): '*If a thing's worth doing, it's worth doing well*'. All answers are real words.

Figure 3 | Magpie crossword issue 166.1 (Chalicea, 2016)