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What is 'manipulation'? A reappraisal

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ABSTRACT

Due primarily to its colloquial function, 'manipulation' is a poor term for distinguishing one healthcare intervention from another. With reports continuing to associate serious adverse events with manipulation, particularly relating to its use in the cervical spine, it is essential that the term be used appropriately and in accordance with a valid definition. The purpose of this paper is to identify empirically-derived features that we propose to be necessary and collectively sufficient for the formation of a valid definition for manipulation. A final definition is not offered. However, arguments for and against the inclusion of features are presented. Importantly, these features are explicitly divided into two categories: the 'action' (that which the practitioner does to the recipient) and the 'mechanical response' (that which occurs within the recipient). The proposed features are: 1) A force is applied to the recipient; 2) The line of action of this force is perpendicular to the articular surface of the affected joint; 3) The applied force creates motion at a joint; 4) This joint motion includes articular surface separation; 5) Cavitation occurs within the affected joint.

1. Introduction

Scientific enquiry often requires researchers to consider the foundations upon which important clinical and academic assumptions have been built. For the professions that use manual therapy, few foundations lie as deep as definitions of the very interventions that distinguish manual therapy from other areas of healthcare. It is difficult for practitioners to make rational decisions about the use of an intervention when that intervention is poorly defined or not mechanistically understood. Indeed, the ramifications of this uncertainty may be more far reaching than judgements made by individual clinicians.

For example, definitions of healthcare interventions may be used by purchasers to make inferences about the potential efficacy, safety and appropriateness of that intervention, when applied to populations (e.g. Shekelle et al., 1991; Coulter et al., 1996; Gatterman et al., 2001). Given that clinical trials have so far provided few clear answers to inform the choice of one physical treatment over another, particularly in relation to musculoskeletal problems (Keller et al., 2007; van der Velde et al., 2008), the perceived characteristics of an intervention are likely to be used to provide clinical guidance. In addition, with reports continuing to associate serious adverse events with manipulation (e.g. Ernst, 2007), particularly relating to its use in the cervical spine, the term should be used appropriately and in accordance with a valid definition.

Manipulation is one intervention for which a satisfactory definition is lacking. Due primarily to its colloquial function, 'manipulation' is a poor term for distinguishing one physical treatment from another. Indeed, so vague is the term that when used in scientific journals, supplementary details are often required to differentiate 'real' manipulation from its manual therapy counterparts (e.g. Keller et al., 2002; Harvey et al., 2003; Skyba et al., 2003; Colloca et al., 2004, 2006; Song et al., 2006). Oversights of this kind may be avoided if what is currently termed 'manipulation' were accurately defined.

The purpose of this paper is to present features proposed to be necessary components of a valid definition of manipulation. A final definition of manipulation is not offered, but arguments for and against the inclusion of these empirically-derived features are presented as a first step in this direction.

2. Defining manipulation

Prior to contemplating a definition of manipulation, it is necessary to consider how a definition should be formed. Established criteria for a *definition* are presented in Table 1 and are compared to those criteria that meet the requirements for a *description*. A useful definition of manipulation should encompass all characteristics that empirical research has shown to be universally valid in *all* parts of the body, yet exclude any

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Table 1
A comparison of the criteria required for definitions and descriptions.

Definition	Description
A statement expressing the essential nature of something	Discourse intended to give a mental image of something experimental
May be stipulated, or assigned meaning	Must derive from observation or experience
When applied to a class of phenomena, must apply fully to all members of the class	When applied to a class of phenomena, may yield an aggregate set of features, all of which need to apply to each particular member of the class

From O'Connor et al., 1997.

characteristic shown to be surplus or redundant in *any* part of the body.

Previous attempts at a definition of manipulation have appeared in diverse sources of literature (representative examples are given in Table 2), and reveal several notable features. Firstly, when compared to the criteria in Table 1, it is clear that most of these previous 'definitions' are actually descriptions. Furthermore, none of these can qualify as definitive as there is variation, and discordance, between them. Lastly, none is empirically-derived using the existing basic science literature on manipulation; a process that has the potential to identify characteristics that may distinguish manipulation from other physical treatments.

One consistent attribute of previous 'definitions' is that they relate to a physical intervention (or *action*) that one person (usually a practitioner) performs upon another (the *recipient*, who may be a healthy subject or patient). General (colloquial) definitions of the term *manipulation* focus entirely upon the action of the practitioner, without conveying the potential importance of the events that occur *within* the recipient. In comparison, many definitions in a therapeutic context describe a proposed mechanical effect (or *response*) within the recipient, which is caused by the action. This mechanical response may be associated with distinct physiological, neurological or psychological responses (Evans, 2002; Cramer et al., 2006; Bolton and Budgell, 2006; Williams et al., 2007). However, rather than including these secondary responses, which have yet to be clearly delineated, we shall follow the convention of prior definitions and limit our discussion to the action of the practitioner and the passive mechanical response within the recipient.

Table 2
Previous definitions and descriptions of manipulation and spinal manipulation.

Definition/description (quotes)	Source
General (colloquial)	
To handle something, or move or work it with the hands, especially in a skilful way	Chambers 21st Century Dictionary, 2009
Therapeutic (general)	
To apply therapeutic treatment with the hands to (a part of the body)	Chambers 21st Century Dictionary, 2009
The therapeutic application of manual force	American Association of Colleges of Osteopathic Medicine, 2006
High velocity, low amplitude passive movements that are applied directly to the joint or through leverage	Chartered Society of Physiotherapy, 2006
A manual procedure that involves a directed thrust to move a joint past the physiological range of motion, without exceeding the anatomical limit	Gatterman and Hansen, 1994
Therapeutic (spinal)	
Spinal manipulation is … the sudden application of a force, whether by manual or mechanical means, to any part of a person's body that affects a joint or segment of the vertebral column"	New South Wales Department of Health, 2001
Spinal manipulation entails high velocity, low amplitude manual thrusts to spinal joints that extend slightly beyond their physiological range of motion	Ernst, 2001

3. Features of manipulation

Several empirically-derived features are likely to be necessary to define 'manipulation'. A necessary feature should be applicable irrespective of the body region in which manipulation is achieved. We consider that, although each feature may not be unique to manipulation, their combination will be. It is this combination that will represent a framework to sufficiently define manipulation. We have divided these features into two categories: (1) the 'action' (that which the practitioner does to the recipient), and (2) the accompanying 'mechanical response' (that which occurs within the recipient). The merits of each identified feature are discussed below.

3.1. Action (that which the practitioner 'does' to the patient)

3.1.1. A force is applied to the recipient

Manipulation involves a force being applied to the recipient. Most commonly, this force is externally generated and is usually applied to the recipient by physical contact at the skin surface (Kawchuk et al., 1992; Herzog et al., 1993a, 2001; van Zoest and Gosselin, 2003). The force may include reaction forces from furniture, such as a plinth or chair (Kirstukas and Backman, 1999) and, in some circumstances, gravitational force may be utilised. The application of force is proposed to be a necessary feature for a definition of manipulation.

3.1.2. The line of action of this force is perpendicular to the articular surface of the affected joint

The earliest biomechanical studies to investigate what is now termed 'manipulation' (Roston and Wheeler Haines, 1947; Unsworth et al., 1971) examined the phenomenon of 'joint cracking' in metacarpophalangeal (MCP) joints. These studies investigated the relationship between joint surface separation and the production of a 'crack' sound (discussed in more detail later). Both studies used a similar design to induce the cracking sound in that the surfaces of MCP joints were separated using 'traction force', which was applied along the length of the finger, perpendicular to the articular surfaces. The results were equally simple: joint surface separation beyond a certain magnitude created an obvious cracking sound and an immediate increase in articular surface separation. For a short, unspecified period this cracking noise could not be repeated; an observation explained by reduced cohesion within synovial fluid due to the presence of tiny bubbles (Unsworth et al., 1971; Mierau et al., 1988; Evans, 2002). Similar findings were found in later studies of MCP 'joint cracking' (Méal and Scott, 1986; Watson et al., 1989).

Importantly, in every study in which the cracking sound in MCP joints has been examined, the force has always been applied along a line of action perpendicular to the articular surfaces of the affected joint. Moreover, the motion produced by this force was joint surface separation, without any obvious 'gliding' motion. As synovial joint surfaces are designed to glide smoothly over one another, the motion produced during this type of MCP joint manipulation is hence distinguished from that produced during typical 'physiological' motion.

A complexity of this feature is that most synovial joints are curved rather than planar, and are not always congruent. Whereas the line of action of the applied force may be perpendicular to one point along the articular surface, this will not be the case with the entire articular surface. Hence, the applied force may be more accurately described as acting perpendicular to a plane that is tangential to a point of contact between the articular surfaces of the joint.

Although the relationship between forces applied to spinal segments during manipulation procedures and the motion that ensues is often assumed to be self-evident, the existence of coupling patterns in spinal segments can preclude such certainty. Limited kinematic data exist for spinal segmental and joint motions during spinal manipulation procedures. However, the little data that are available do appear to validate this proposed feature in the spine (Evans, 2009).

Bereznick (2005) measured substantial force applied perpendicular to the skin surface during side-posture lumbar manipulation. Due to the negligible friction between the skin and the underlying tissues (Bereznick et al., 2002), the line of action of the majority of this force can be assumed to have been parallel to the transverse plane of the recipient. Additionally, Cramer et al. (2002) confirmed that the same side-posture lumbar spine manipulation technique produces transverse rotation of lumbar spinal segments. Since transverse rotation in the lumbar spine is not obviously coupled with any other motion (Legaspi and Edmond, 2007), the applied force is again likely to act along the transverse plane of the recipient. In turn, the approximately planar articular surfaces of all lumbosacral posterior joints are perpendicular to the transverse plane; typical lumbar zygapophysial joints (L1–L5) are aligned close to the sagittal plane, whereas those of the lumbosacral (L5–S1) joints are more frontally orientated (Giles, 1997; van Schaik et al., 1997; Singer et al., 2004).

Evidence for a similar relationship exists in the thoracic spine. Several studies (Herzog et al., 1993a, 2001; Gál et al., 1995) have shown that manipulation forces are applied in a posterior-anterior direction, parallel with both sagittal and transverse planes, and therefore perpendicular to the frontal plane. In contrast, the articular surfaces of typical thoracic zygapophysial joints (T4–10) are known to be frontally orientated (Singer et al., 2004). Unfortunately, there are limited kinematic data available for cervical spine manipulation, but the small amount that does exist also provides support for this proposed feature (Evans, 2009).

3.1.3. The magnitude of this force increases to a peak over a finite period of time

The available data demonstrate that the magnitude of the applied force varies considerably between individuals, but consistently increases from zero over a finite period of time until a peak force is reached, after which the magnitude decreases once again to zero, in a single, non-repeating cycle. The increase and decrease of the force is not necessarily linear, sometimes taking the form of several distinct phases of unequal duration that vary with the location of the manipulated joint (Roston and Wheeler Haines, 1947; Unsworth et al., 1971; Watson et al., 1989; Hessell et al., 1990; Kawchuk et al., 1992; Kawchuk and Herzog, 1993; Herzog et al., 1993a; Herzog, 2000).

These observations suggest temporal limits for manipulation forces, in contrast to other manual therapeutic interventions (e.g. mobilisation), which may consist of periodical, repeating phases (Lee et al., 2000). However, it is difficult to justify that such force-time constraints are necessary for manipulation. It is feasible that manipulation could still be achieved if the force-time characteristics varied from that typically observed. Furthermore, other interventions may be modified to share such characteristics. Hence, specifying the time frame over which force is applied is not currently proposed as a necessary criterion to define manipulation.

3.2. Mechanical response (that which occurs within the recipient)

3.2.1. The applied force produces motion at a joint

The force applied to the recipient induces motion between the articular surfaces of a joint. This is a fundamental feature of manipulation and other manual therapy interventions (Lee et al., 2000), and is frequently indicated in previous descriptions and definitions (e.g. Table 2). We consider this criterion to be necessary.

While manipulation is often applied with the intent of producing an effect at a specific joint (or joints), research has demonstrated that some manipulation techniques are not sufficiently accurate to always affect the chosen, ‘target’ joint (Ross et al., 2004). It is therefore more precise to refer to the ‘affected’ joint rather than the ‘target’ joint.

3.2.2. This joint motion always includes articular surface separation

The applied force induces motion between the articular surfaces of the affected joint, and when measured, articular surface separation (gapping) has always been observed (Roston and Wheeler Haines, 1947; Unsworth et al., 1971; Mierau et al., 1988; Watson et al., 1989; Watson and Mollan, 1990; Cramer et al., 2002). We propose that this is a necessary criterion for a definition of manipulation as few, if any, other manual therapeutic interventions appear to produce this type of joint motion.

3.2.3. The velocity of joint motion is variable

One of manipulation’s most common pseudonyms is the ‘high velocity–low amplitude thrust’ – a composition of biomechanical terms frequently appearing in prior ‘definitions’ (e.g. Table 2). Velocity is the rate of change of displacement with respect to time. High velocity joint motion may occur during everyday activities (e.g. throwing, running or kicking), as well as during passive manual or instrument-assisted procedures (e.g. manipulation and mobilisation). Hence, the velocity of joint motion alone cannot define manipulation. Moreover, several studies have shown that manipulation may be achieved at relatively low velocity joint motions (Unsworth et al., 1971; Méal and Scott, 1986; Watson et al., 1989; Suter et al., 1994). Thus, given the current available data, velocity is not considered a necessary criterion.

3.2.4. The sum displacement of the articulating bones is usually zero

Importance has been attached to the amplitude of joint motion achieved during physical interventions, and a ‘grading’ system has been proposed (Maitland, 1966). However, the sum (resultant) displacement or deformation of tissue does not appear to be a necessary feature for the achievement of manipulation. Assuming that tissues have not undergone damage through being deformed beyond their elastic limit, are no longer under the action of any external force, and are under constant environmental temperature (Watson et al., 1989; Kernohan et al., 1990) and pressure (Semlak and Ferguson, 1970), all studies that have measured bone displacement before and after manipulation show no lasting change, once elastic tissue deformation has been allowed to recover (Unsworth et al., 1971; Mierau et al., 1988; Watson et al., 1989; Gál et al., 1994, 1995, 1997; Tullberg et al., 1998; Cramer et al., 2002). As such, the final resultant displacement of the articulating bones following a manipulation is usually zero. This raises some concern with use of the term ‘adjustment’, which conveys a notion of lasting tissue displacement.

This feature was considered useful as it distinguishes manipulation from procedures to reduce a dislocation or realign fractured bone. However, it is conceivable that a manipulation delivered with excessive force may damage some of the joints restraining tissues, and result in lasting tissue displacement or deformation. Moreover, a manipulation that induces tissue damage is still manipulation, irrespective of an adverse outcome. Hence, the criterion for zero tissue displacement seems unnecessary for the definition of manipulation.

3.2.5. Cavitation occurs within the affected joint

Associated with joint surface separation is the elicitation of a high frequency vibration that manifests as an audible ‘click’ or ‘crack’ sound (Roston and Wheeler Haines, 1947; Unsworth et al., 1971; Watson et al., 1989). These vibrations are readily measured using microphones or accelerometers, and have been investigated in various joints across several studies (Méal and Scott, 1986; Watson et al., 1989; Herzog et al., 1993b; Gál et al., 1995; Reggars and Pollard, 1995; Reggars, 1996a,b, 1999; Beffa and Mathews, 2004; Bolton et al., 2007).

The most likely and widely accepted explanation for this audible sound during joint manipulation is a process known as cavitation, occurring within the synovial fluid of the affected joint (Evans and Breen, 2006). Cavitation is an engineering term used to describe the formation and activity of bubbles (or cavities) within fluid, which are formed when tension is applied to the fluid as a result of a local reduction in pressure (Unsworth et al., 1971; Trevena, 1987; Young, 1999). Evidence for this explanation of the sound has come in several forms.

There is face validity for cavitation as the explanatory mechanism of ‘joint cracking’. The earliest scientific study of the phenomenon identified articular surface separation as a key component (Roston and Wheeler Haines, 1947). The characteristic triphasic force–displacement graphs obtained during increasing joint surface separation (Roston and Wheeler Haines, 1947; Unsworth et al., 1971; Watson et al., 1989), combined with the divergent return pathway, are strongly suggestive of a rapid and temporarily irreversible change in the cohesive properties of synovial fluid, which was brought about by increased intra-articular volume and consequent decreased intra-articular pressure. In synovial joints, the reduction in intra-articular pressure is likely only achieved with a corresponding deformation of the joint capsule (Brodeur, 1995), although this suggestion remains speculative.

Radiographs have consistently demonstrated a radiolucent region between the articular surfaces of the affected joint, immediately following the elicitation of the sound, whilst these surfaces remain separated (Fick, 1911; Dittmar, 1933; Nordheim, 1938; Fuiks and Grayson, 1950; Unsworth et al., 1971; Watson and Mollan, 1990). No study has measured how long this state may persist by continuously maintaining joint surface separation, although theoretically this could be indefinitely (Roston and Wheeler Haines, 1947).

Finally, several studies have shown that the sound cannot be elicited more than once within a relatively short period of time after the articular surfaces of the affected joint are allowed to return to their resting configuration (Roston and Wheeler Haines, 1947; Unsworth et al., 1971); a period that has been shown to extend as long as 90 min following lumbar spine manipulation (Bereznick et al., 2008). Furthermore, the location and quantity of these high frequency vibrations recorded during manipulation procedures in the spine is consistent with them originating from the synovial zygapophysial joints (Ross et al., 2004; Bereznick et al., 2008).

One may ask whether cavitation is a necessary feature of manipulation? Physiological changes may take place during ‘manipulation’ in the absence of cavitation (e.g. electromyographic signals). However, cavitation is associated with distinct osteokinematics (Unsworth et al., 1971; Watson et al., 1989; Watson and Mollan, 1990; Gál et al., 1995; Cramer et al., 2002). In addition, clinicians frequently regard cavitation as an indicator of success in the technical delivery of a manipulation (Evans and Breen, 2006). Conversely, some commentators consider cavitation to be an unnecessary outcome of manipulation because research has yet to demonstrate an association with clinical outcomes (Flynn et al., 2003, 2006). Nevertheless, for the purpose of defining manipulation, the clinical success, or otherwise, of the intervention is irrelevant. By corollary, the occurrence of surgery, acupuncture or any other physical intervention would not be defined by a successful or failed clinical outcome. Cavitation may also, on occasion, occur spontaneously during everyday movements, or during extreme joint motions that may damage a joint. Hence, the occurrence of cavitation in isolation cannot constitute a definition of manipulation.

We propose that cavitation *is* a necessary feature of manipulation. However, we are aware that the inclusion of this criterion will be controversial for the reasons given above. It is also reasonable to argue that cavitation is *not* the intended outcome of other types of manual therapeutic interventions. For example, traction of peripheral joints has been shown to result in joint surface separation (Hsu et al., 2008). If such a procedure resulted in cavitation, then this would, by definition, be a manipulation. By contrast, traction of the lumbar spine does not result in zygapophysial joint surface separation (Humke et al., 1996); a likely consequence of the complex kinematics of spinal segments (Evans, 2009). Alternatively, if all other proposed criteria were present, yet cavitation was not achieved, this would not fulfil all necessary criteria of a ‘manipulation’ so should not be referred to as such.

4. Summary

Of the features discussed above, those we propose to be necessary for the achievement of manipulation are summarised in Table 3. We have attempted to retain the minimum number of features. Collectively, these features should sufficiently constitute the required components of a valid definition. Used in isolation, each of these features is insufficient to define manipulation; their sufficiency is dependent upon their collective occurrence. This is consistent with defining causal mechanisms as a set of factors that are jointly sufficient to induce an outcome event (Rothman, 1976); under the omission of just one factor, the outcome would be different.

Fig. 1 demonstrates the relationship of the proposed necessary features of manipulation compared to other manual therapy interventions, illustrating their potential importance within a wider empirically-derived taxonomy of manual therapy.

An important attribute of our proposed features is that they are explicitly divided into two categories: the ‘action’ (that which the practitioner does to the recipient) and the ’mechanical response’ (that which occurs within the recipient). Interestingly,

Table 3
Proposed necessity of manipulation features.

	Necessary
Action (that which the practitioner does to the recipient)	
A force is applied to the recipient	Yes
The line of action of this force is perpendicular to the articular surface of the affected joint	Yes
The magnitude of this force increases to a peak over a finite period of time	No
Mechanical response (that which occurs within the recipient)	
The applied force creates motion at a joint	Yes
This joint motion includes articular surface separation	Yes
The velocity of joint motion is variable	No
The sum displacement of the articulating bones is usually zero	No
Cavitation occurs within the affected joint	Yes

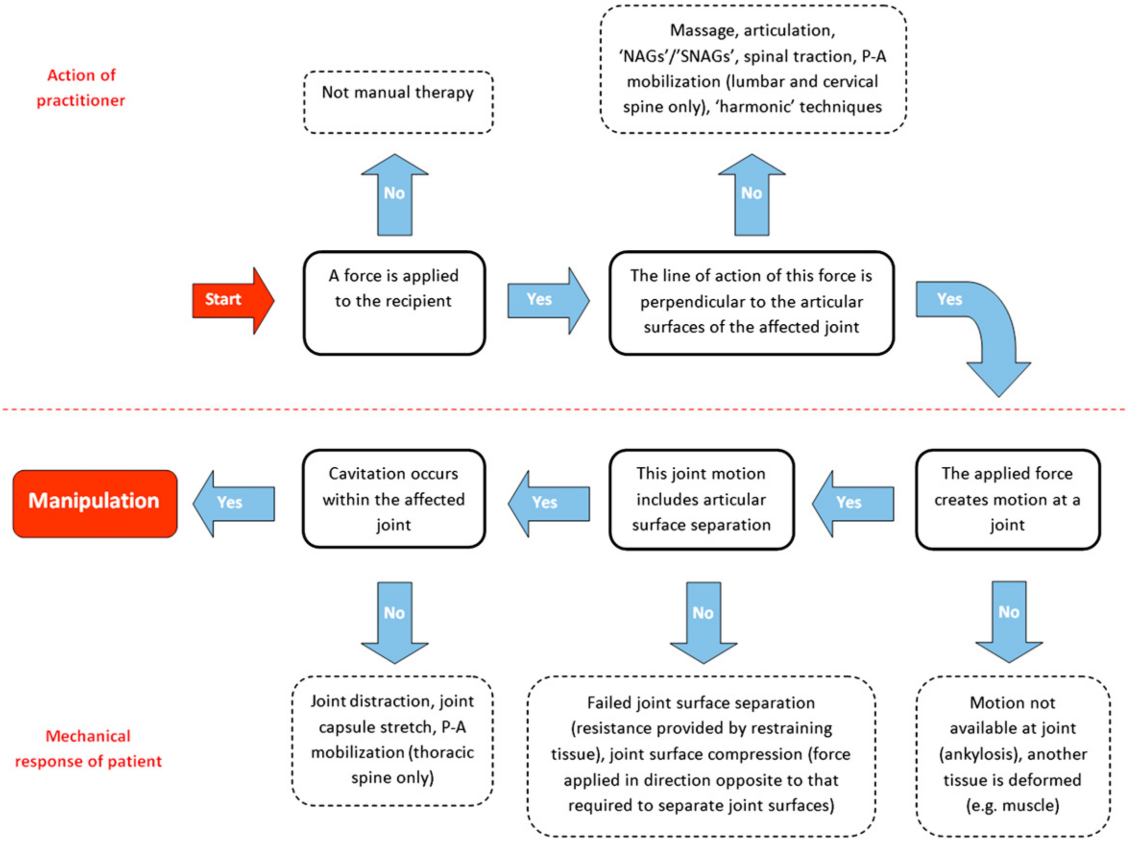

Fig. 1. The relationship of the proposed necessary features of manipulation, compared with other manual therapy interventions.

whilst all of the 'action' features are included at the discretion of the practitioner (and if any are excluded, the minimally sufficient criteria for 'manipulation' would not be met), there is a causative chain in operation with the 'response' features; once all of the 'action' components have been achieved, the induction of some joint motion is necessary for the occurrence of joint surface separation, and in turn this is necessary for the occurrence of cavitation (Fig. 1).

5. Conclusion

We have identified empirically-derived features of manipulation that we propose to be necessary for a valid definition, and have provided arguments for and against their inclusion in such a definition. In addition, we have specified that each feature must occur in order that the required defining criteria for manipulation are met and that it be clearly distinguished from other manual therapeutic interventions within a wider empirically-derived taxonomy of manual therapy.

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