Small Arms, Small Data

Small arms shooting accuracy and the small data problem

John D Salt, Cranfield Defence and Security 28 April 2016 revised 01 and 05 July 2016

Abstract

This paper explores how small-arms aiming errors appear to vary with range. In particular it investigates the question of whether a "proximity effect" exists, reducing accuracy at close range.

Data on small-arms hitting rates is sparse. The paper analyses nineteen sources of data, giving 83 data points; combat data is augmented with data from police shootings, range trials, OR models and qualification scores. The paper explains the assumptions made in order to compensate for gaps in the data, such as target size.

Data points are reduced to a common basis of angular error, which would produce the observed hitting rate if shooting at a visible static rectangular target at the stated known range. This subsumes all errors normally included in ballistic error budgets, plus the uncertainty of target location if firing at targets not clearly visible.

The data available indicates that the accuracy of small-arms fire decreases with proximity to the target, so that the hitting rate does not increase as much as would otherwise be expected at closer ranges. The effect seems to apply across different types of data source, weapon, and fire, up to about 100 metres.

The paper discusses possible explanations for the effect: prevalence of close terrain in the combat sample, restricted visibility, targets reducing their exposure time close to the enemy, uncertainty as to true target position, psychological stress due to enemy proximity, and a transition to pointed rather than aimed shooting. Each may be a contributory factor, but it is tentatively concluded that a hastier shooting style arising from psychological stress provides most of the explanation.

Finally the paper suggests some directions for future work, the most important of which is clearly to add to the data available on this subject.

Background

Since the earliest days of operational research, practitioners have studied problems in hit probability. Such calculations are normally done by assuming a Gaussian dispersion of shots over the target, and calculating the proportion of the relevant Gaussian curve that covers the target. A general assumption, when drawing up an error budget for a ballistic weapon, is that angular errors are constant with range to the target. One obvious exception is rangefinding error, which one would expect to grow with range. This paper explores the way small-arms aiming errors appear to vary with range in operational small-arms shooting. In particular it investigates the question of whether a "proximity effect" is observable, reducing accuracy at close range.

The "proximity effect" is suggested in *Brains & Bullets* [Murray 2013], whereby defensive fire becomes less effective and an attacker's forward movement might stall at about 50 metres. Unfortunately *Brains & Bullets* does not give references to the sources for this conclusion, nor any numerical estimate of the magnitude of the effect.

Published by ISMOR. This is the Author Accepted Manuscript issued with: Creative Commons Attribution Non-Commercial License (CC:BY:NC 4.0).
The final published version (version of record) is available online at http://www.ismor.com/ismor_archives/33ismor_archive/33ismor_index.shtml. Please refer to any applicable publisher terms of use.

Two separate WW2 sources report psychological effects on the accuracy of infantry shooting against tanks. *The effectiveness of PIAT shooting* [WO 291/153] reports range trials in which the percentage of hits "…is noticeably greater with crossing and receding targets, and firers put this down to the 'sense of hurry' that seems to exist when a tank is fast approaching. This appears to be a genuine effect, and not due to chance errors." I conducted some further analysis and found no substantial effect of range on projectile dispersion, only of target aspect. *The A45 flame gun versus the Panzerfaust* [WO 291/1060] reports Panzerfaust hit probabilities from operational evidence, which show a substantial apparent drop in aiming accuracy with target proximity. The report states that "The disproportionally large number of misses at close range is thought to be due either to the fact that short-range firing is nerve-racking to the firer, or to the large angular velocities of the target as it reaches crossing point." As this report does not mention target orientation, it is impossible to comment on the influence of tank aspect on the firer's nerves.

The effectiveness of small arms fire is known to vary enormously with tactical circumstances. On one hand, it is remarkable how far away you can be killed by a rifle bullet; on the other, it is amazing how close a shooter can be and still miss. If it were true that "short-range firing is nerve-racking to the firer" against personnel targets as well as tanks, this would go a long way to explain the apparently extreme variation.

One hears folk tales to the effect that hitting a man requires the expenditure of his own weight in ammunition. Numerical data on the number of rounds needed to inflict a casualty is, however, very hard to come by. As Wallace and Crompton put it in 1946 [WO 291/965]:

> *In general the amount of reliable information on almost any aspect of battle tends to be much smaller than is often supposed... These studies illustrate how slender is the basis on which much of the theory of war depends, and emphasise the need for more knowledge in many directions.*

Robinson [Robinson 1994] divides data into three categories, which he designates as A, B and C. Category C data is that which "are neither available nor can they be collected." For a long time I thought that data on the number of bullets required to achieve results in combat might prove to be Category C, but it turns out that a few snippets are available, and can be supplemented with data from other sources that are somewhat alike.

Data and Assumptions

I collected data on the expected ballistic dispersion, hit probability, or hitting rate achieved by modern small arms from a number of sources. I have characterised the types of source as:

Combat	In action against live enemy who can shoot back. May involve reduced visibility.
Police shootings	US police firearms incidents, with or without return fire. May involve reduced visibility.
Range trials	Shooting on a range as part of a trial, perhaps with "realistic" elements of shooter stress or target layout, but with good visibility and no return fire.
Qualification score	Shooting on a range to achieve a stated training standard, in good visibility and with little stress.
OR model	A figure given by OR analysts, typically for use in a computer simulation.

While it would obviously be preferable to collect data only from combat, the extreme sparsity of such sources makes it necessary to accept others. See Annex A for the data collected.

The data collected came from only 19 sources, and provided only 83 data points. Of these, 22 are from combat, 8 from Police shootings, 35 range trials, 5 qualification scores, and 13 OR models. The following table summarises the data sources used, in order of fruitfulness:

Reference	**Source Title**	**Data Points**
WO 291/476	*Comparison of rifle, Bren and Sten guns*, 1944	12
Harris 1993	*Spartan II: An Instructional High Resolution Land Combat Model*, MSc thesis, Edwin H Harris, Air Force University, March 1993	10
WO 291/1668	WO 291/1668, *Performance of small arms weapons including .280 (7mm) rifle, used in machine carbine role in Malaya*, 1953	9
Aveni 2003	*Officer-Involved Shootings: What We Didn't Know Has Hurt Us*, Thomas J Aveni, Law and Order Magazine, August 2003	8
FB 181 1945	Film Bulletin No. 181, Army Pictorial Service, US Army Signal Corps, 1945	7
Hall & Ross 2009	*Bang on Target: Infantry Marksmanship and Combat Effectiveness in Viet Nam*, Dr Bob Hall and Dr Andrew Ross, Australian Army Journal Vol. VI no. I, pp. 139-156	6
CDEC 1962	*Rifle Platoon Firepower Experiment*, US Army Combat Development Experimentation Center, Fort Ord, CA, March 1962	6
Lappi 2012	*Jalkaväen tulen vaikutuksesta* (On the Effect of Infantry Fire), 1954, in Computational Methods for Tactical Simulations, Esa Lappi, Helsinki, 2012	4
Jovanović et al 2012	*The Effects of Basic Military Training on Shooting Tasks in Conditions of Sleep Deprivation*, Mario Jovanović, Goran Sporiš, Josip Šopar, Dražen Harasin and Dario Matika, Kinesiology Vol. 44 no. 1 pp. 31-38, 2012	4
FM 3-22 9 2008	FM 3-22 9 2008, *Rifle Marksmanship M16-/M4 Series Weapons*, Department of the Army, Washington, DC, 12 August 2008	3
CQB 1961	Infantry Training Volume III, Ranges and Courses, Pamphlet no. 33, *Close Quarter Shooting*, the War Office, 1961	2
Scott et al 2015	*The Effect of Stress on Marksmanship*, Adam Scott, Rob Shaul and Sam McCue, Mountain Tactical Institute, Jackson, WY, 2015	2
Zuber 2010	*The Mons Myth*, Terence Zuber, The History Press, Stroud, 2010	2
Lind et al 1971	*FAST-VAL: A Study of Close Air Support (A Briefing Summarizing the Comparisons of Model with Combat Results and Illustrating the Influence of Supporting Arms on Fire-fight Outcomes) , J R Lind, K Harris, and S G Spring, R-811-PR, The Rand Corporation, Santa Monica, CA, November 1971*	2
PCD undated	*Good to Knows*, Platoon Commanders Division, School of Infantry, Warminster, undated	2
Spring et al 1971	*FAST-VAL: Case Study of an Attack in the DMZ, 8 October 1968, S G Spring, J R Lind and K Harris, R-818-PR, The Rand Corporation, Santa Monica, CA, November 1971*	1
WO 291/471	*Weight of small-arms fire needed for various targets*, 1944	1
Ewell & Hunt 1995	*Sharpening the Combat Edge: The Use of Analysis to Reinforce Military Judgment*, Lt-Gen Julian J Ewell and Maj-Gen Ira A Hunt, jr, Department of the Army, Washington DC, 1995	1
Mayne 1888	*Infantry Fire Tactics*, Charles Blair Mayne, Gale & Polden, Brompton, 1888	1

A source that does not directly specify an expected dispersion should ideally state the following:

1. The weapon used
2. The range to the target
3. The dimensions of the target
4. The type of fire delivered (aimed or pointed, burst or single shot)
5. The conditions prevailing (darkness, brief target exposures, and so on)

Very few sources stated all of these, so some assumptions had to be made.

Most sources stated the weapons used unambiguously. One Finnish data source [Lappi 2012] characterised the weapons only by general class, but knowing the standard types of rifle, self-loading rifle, SMG and automatic rifle equipping the Finnish army at the time it is possible to be fairly sure what they are. Where ".303 rifle" is stated, it is considered irrelevant whether this is a No.1 or No.4 rifle. I counted M1 and M2 carbines as rifles, and as both models (one single shot and the other selective fire) were lumped in together, arbitrarily categorised them as delivering single shot fire.

The following table summarizes all the weapons that feature in the data collected, arranged into the weapon categories I have used:

Rifle	Martini-Henry, Mauser 98, Mosin, Lee-Enfield, M1 or M2 carbine, SVT, SLR, M14, AK, AR15, M16, M4 .303, 7.92x57, or 7.62x54R bolt-action rifle, or 7.62x51, 7.62x39, 7.62x33 or 5.56x45 gas-operated self-loading or selective-fire rifle or carbine
SMG	Thompson, Suomi , MP40, Sten, M3, Owen .45 ACP or 9mm Luger blowback-operated SMG
MG	M1917, M1919, Lahti-Saloranta M26, lMG-34, Bren, sMG-42, M60, RPD 7.62x63, 7.62x54R, 7.92x57, .303, 7.62x51 or 7.62x39 gas- or recoil-operated magazine- or belt-fed machine gun
Handgun	9mm or 10mm automatic pistol or .38 Special revolver

The range to the target is sometimes stated as a range band. In such cases I took the range to be half way between the start and end of the band. In the case of an open-ended band, such as "over 100 yards", I assumed the range band to have the same width as the band next to it. If a range was given in yards I have converted it to metres.

The combat and police shooting sources never state the dimensions of the target, and those for range trials do not always do so. For range trials, it has been possible to estimate the sizes of UK figure 11 and US type E, type F, and 10-inch challenge targets. For other cases I assumed a general target size of 0.5m by 0.5m, giving a target area of 0.25m^2. This is smaller than the STANAG target area for a standing man (0.37m^2), but close to the size of head-and-shoulders target commonly used to represent a prone man. In the one combat case where the targets were known to be occupying slit trenches, I took the target area to be the same as that specified for men occupying slit trenches in [WO 291/471].

The type of fire delivered is never stated for combat and police shootings, and not always for the range trials. I have inferred it from the type of weapon used. MGs and SMGs are designed to be fired in bursts, so I assumed always were unless explicitly stated otherwise. Some rifles are capable only of single shots (bolt-action and self-loading rifles), and I have ignored the occasional Australian practice of modifying the SLR to fire bursts. Selective-fire rifles (M14s, M16s and AKs) I assumed to be fired in single shots, except for the M16 in ambushes by the 1st Australian Task Force (1ATF) which I considered to be fired in bursts. The Croatian special forces practice of firing AKs using a "double tap" [Jovanović et al 2012] I counted as firing single shots, as each shot requires a distinct trigger pull – it is not a two-round burst.

Some trials cases specify conditions, and all were in daylight, but again there is no information for combat and police shootings. A particular deficiency of the data is that, with the exception of one case [PCD undated], no information is given about the weight of enemy return fire. However, a significant proportion of 1ATF ambushes (42%) took place in darkness [Hall & Ross 2009]. The availability of night vision devices for 1ATF is not known, so the only data point known to be employing night vision equipment is the one from Ewell and Hunt, trained snipers using sniperscopes at night securing one hit in every six shots at an average range of 148 metres. The NYPD police shootings include up to 77% of cases in restricted lighting, and Baltimore PD 59% [Aveni 2003]. Presumably there is some degree of street lighting, so this is not the same as night in the jungle.

Much of the combat data comes from two sources, one on the 1ATF in Vietnam [Hall & Ross 1993] and the other on British troops in Malaya [WO 291/1668 1953]. These may not be representative of the full range of close combat experience in the 20th century. In both cases combat occurred at close range in close terrain. In the Vietnam actions the average combat range was 23 metres, and in Malaya ambushes took place at an average range of 33m and patrol encounters 70m.

It is not possible to say much about the levels of skill and experience of the troops in the combat examples, except to say that all are from forces recruited at least partly by conscription. All those from regular forces would have received sound basic training in fieldcraft and weapon handling, whereas the standards of irregular opponents (for whom no hitting rates are reported) might not have been so high. The only cases involving troops that might be considered in any sense "elite" are the data points from US snipers from [Ewell & Hunt 1995] and from the action at Rasau [PCB undated] where a force including Indonesian commandos confronted a relatively poorly prepared force from the HQ company of a Gurkha battalion. None of the cases covered by the data appear to involve AFVs, artillery preparation or formal assaults – even at Rasau, where shouts of "charge!" were heard, but not apparently obeyed. It seems, therefore, that whatever levels of psychological stress prevailed in these actions, they do not represent such extreme and debilitating levels as might apply on the receiving end of a close assault following an artillery bombardment.

All the police shootings occurred at very close ranges, being carried out with handguns. The data summarize the broad range of officer-involved shootings, and it is not known what proportion of the incidents involved return fire. Evidently the standard of criminal shooting might vary widely, but again no hitting rates are reported.

Method

I reduced all data obtained to the common form of an expected ballistic dispersion, in mils (using the NATO mil, 1/6400 of a circle), as a single simple numerical characterisation of the accuracy of the shooting. This measure of accuracy seems preferable to P(hit) or bullets per hit because it is independent of target size, and nominally independent of range. It therefore enables a fair comparison between the accuracy of shooting at targets of different sizes (degrees of exposure) at different ranges.

Where data gave ballistic dispersions (usually from OR models) I used it directly. Where the data gave hit probabilities or hitting rates I ran it through a “reverse P(hit)” spreadsheet written for the purpose. Given the number of shots needed to secure a hit, the range, and the target dimensions, this tries to find the angular dispersion of shooting that would just achieve the specified hitting rate.

Usually I assume that the vertical and horizontal components of overall dispersion are the same. This is certainly a reasonable assumption for modern flat-shooting rifle ammunition up to 300 metres. Above 300m, range estimation errors begin to produce an increasingly significant vertical component. However, there are any number of possible answers to the reverse P(hit) problem if horizontal and vertical elements are allowed to vary separately.

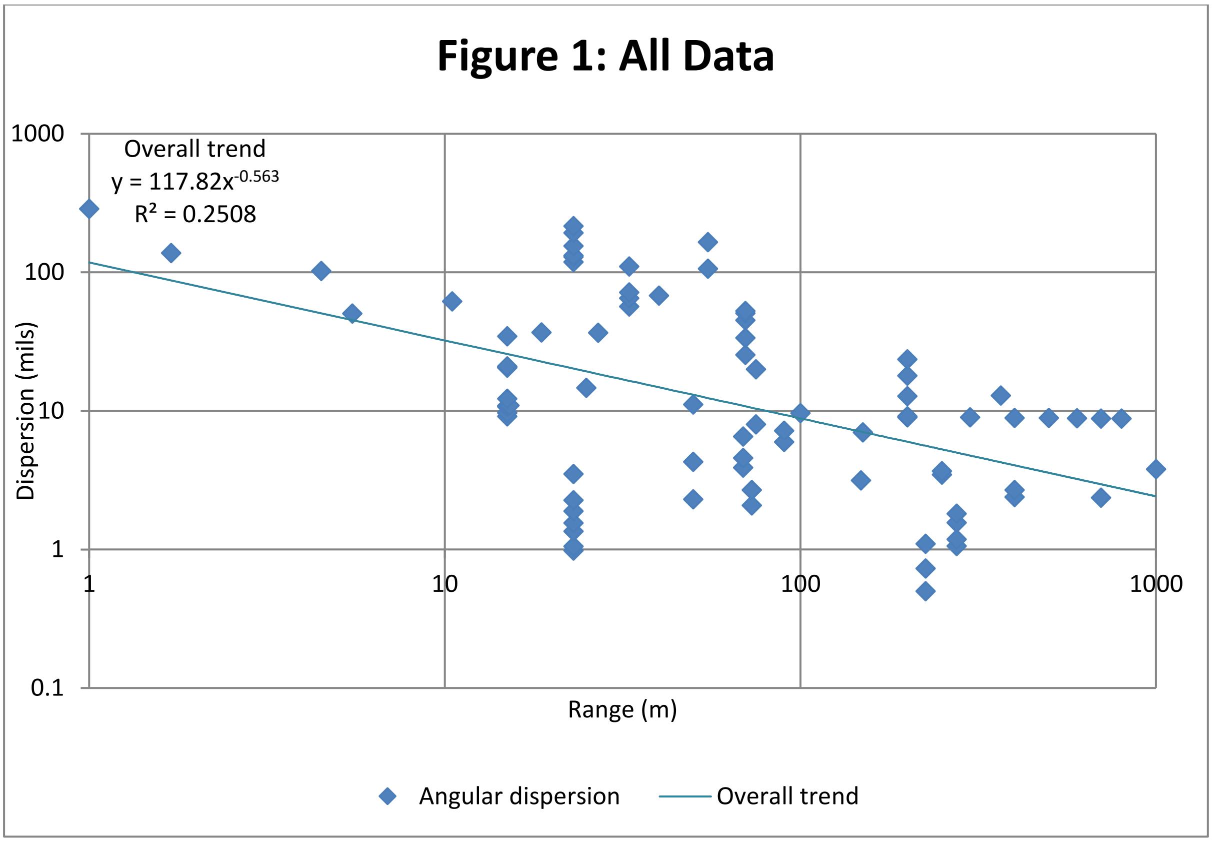
A conventional method of calculating P(hit) on a rectangular target is to find, for each target dimension, the proportion of a Gaussian curve covered by the target. This gives the P(hit) in that dimension, and multiplying the P(hit) in elevation by the P(hit) in azimuth gives the overall P(hit). For more detail on the method, see for example exercises 5 and 6 in [Shephard et al 1988]. The “reverse P(hit)” spreadsheet performs the opposite calculation, starting with the P(hit) and, assuming a square target, taking its square root to find the P(hit) in each dimension. Knowing the target dimensions, it then finds the standard deviation of the Gaussian curve that would have a fraction of itself covered that would correspond to the P(hit). In Microsoft Excel terms, this calculation uses the NORMSINV function, rather than the NORMSDIST used in conventional P(hit) calculations.

In order to confirm the results, I fed the derived dispersion into a P(hit) calculator to check that it produced the specified hitting rate on the specified target at the stated range.

The dispersion so calculated is a global measure of all causes of shooting inaccuracy. Given the precision of which even mass-produced firearms and ammunition are capable, most of this inaccuracy will come from sources that are either human or tactical factors, rather than technical ones. Human factors might include decreased aiming accuracy, poor holding, or trigger-snatching as a result of stress. Tactical factors might include the necessity of snap-shooting against targets exposed only briefly, or by shooters popping up for a short interval before resuming cover. They may also include the angular uncertainty entailed in firing into cover where a target was recently seen to disappear; much combat shooting is conducted without a clearly-visible human target, even at close ranges.

I then charted the processed dispersion data as a log:log scatter plot of dispersion against range, and plotted a linear trend line [see Figure 1].

This showed a definite tendency for dispersion to increase at closer ranges, contrary to the assumption that it should remain constant with range.



By plotting different partitionings of the data into subsets, I investigated a number of possible explanations for this effect.

Results

Different partitonings of data explored were:

1. Grouped by source [Figure 2]
   The trend remained evident for each type of data source considered separately. The trend line for combat, police shootings and qualification scores was noticeably steeper than that for range trials or OR models.
   As expected, the general levels of dispersion for the non-combat sources were lower than those for combat and police shootings. However some trials results overlapped with the combat and police shooting results, and OR models used dispersions towards the high end of the trials results.

2. Grouped by weapon type [Figure 3]
   Handguns and sub-machine guns fire low-velocity pistol cartridges from short barrels. This makes them inherently less accurate weapons than rifles and MGs, which fire high-velocity rifle cartridges from long barrels. One might therefore expect handguns and SMGs to be used only at short ranges, whereas rifles and MGs can be used at short or long ranges. This might explain the overall trend if results from the inaccurate weapons are concentrated at the close ranges.
   The trend of increased dispersion with proximity remained clearly visible for handguns (8 cases), rifles (44 cases), and MGs (18 cases). The trend line was steeper for MGs than for

handguns and rifles. Unexpectedly the reverse trend was shown for SMGs (13 cases). This might have been influenced by three very accurate results firing single shots at close range from one trial.

Figure 2: Partitioned by Source Type

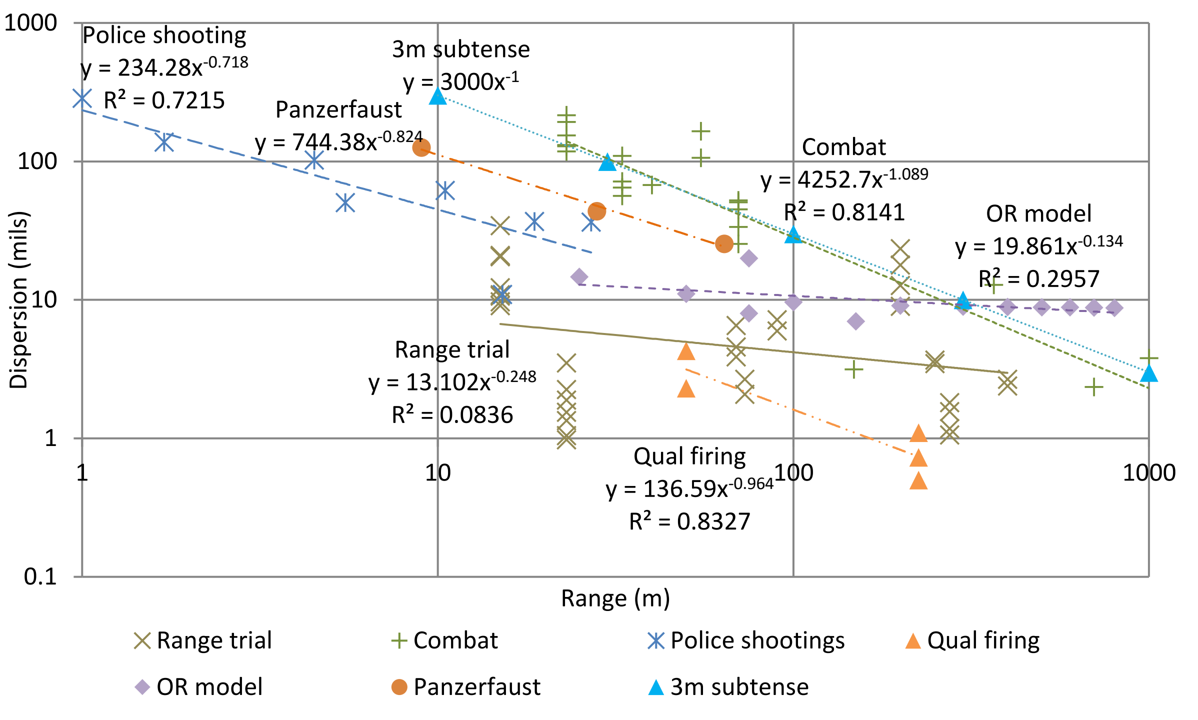
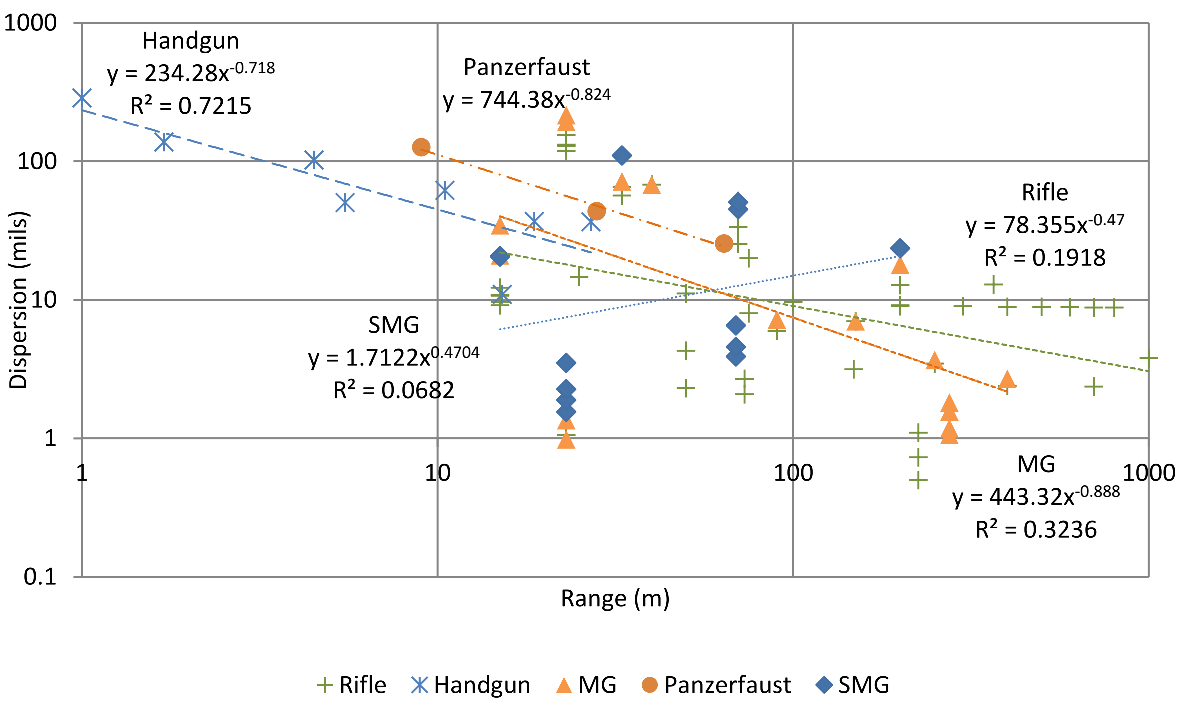
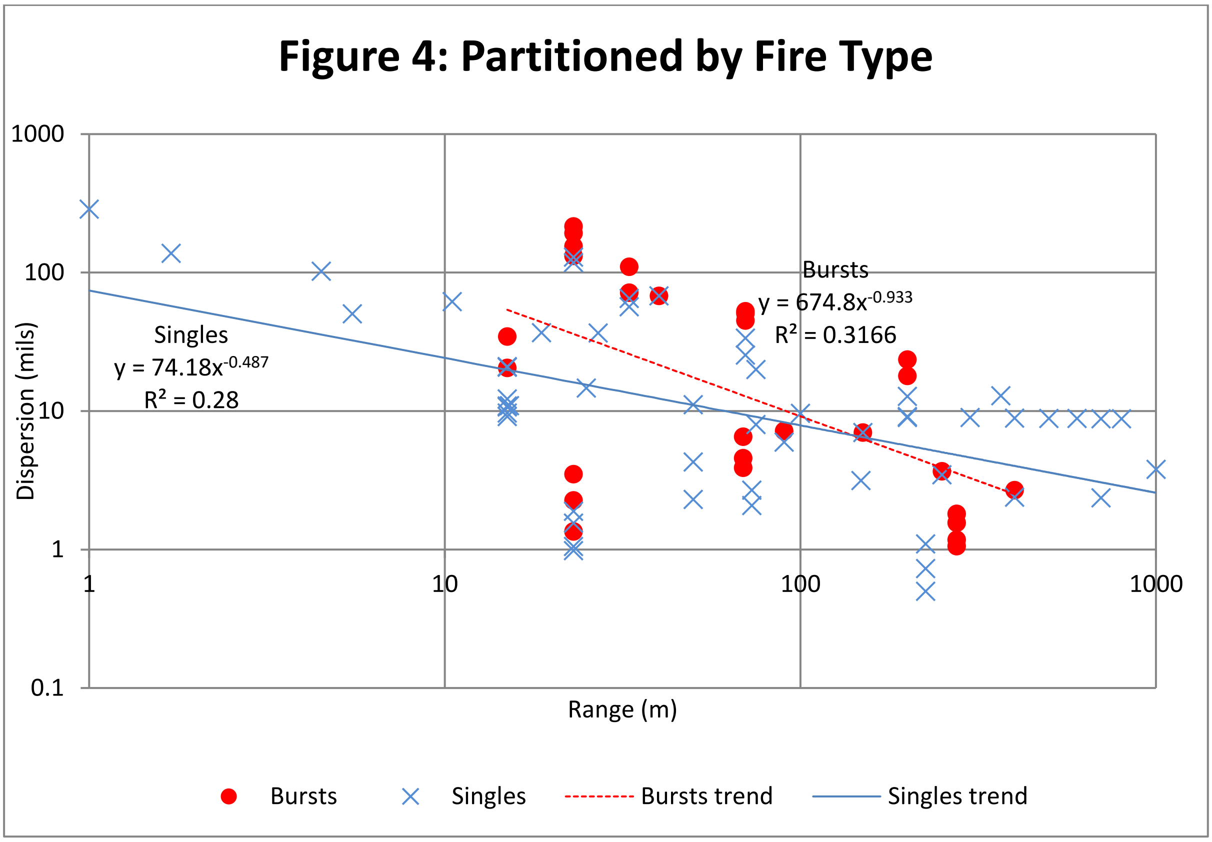


Figure 3: Partitioned by Weapon Type



3. Grouped by fire type [Figure 4]
   The trend of increased dispersion with proximity remained clearly visible for both burst-firing and single-shot weapons. The trend line was steeper for burst-firing weapons than for single shot.



4. Grouped by range [Figures 5 to 8]
   One might reasonably expect to see a transition from deliberate aimed fire to instinctive pointed fire as the range closes to close quarter battle (CQB), as described in [Stavers 1944]. Rowland and Speight's rural infantry battle model takes 30 metres as changeover point to CQB; the US Army defines it as 50 metres. The data was partitioned in four different ways, at 30, 50, 75 and 100 metres.
   A break at 30 metres showed a slightly steeper trend line at 30m and below (31 cases) compared with over 30m (50 cases). See Figure 5.
   A break at 50m (the most even range partitioning possible, with 39 cases at 50m or below and 42 cases over 50m) showed trend lines of very similar slope, but still slightly steeper at the closer ranges. See Figure 6.
   A break at 75m showed the usual trend at 75m and below (51 cases), but an almost flat trend line over 75m (30 cases). See Figure 7.
   A break at 100m showed the usual trend at 100m and below (54 cases), but above 100m (27 cases) the trend reverses, showing a slight increase in dispersion with increased range. This is the direction of trend one would expect if factors such as crosswind drift and rangefinding error were significant factors in overall dispersion. See Figure 8.

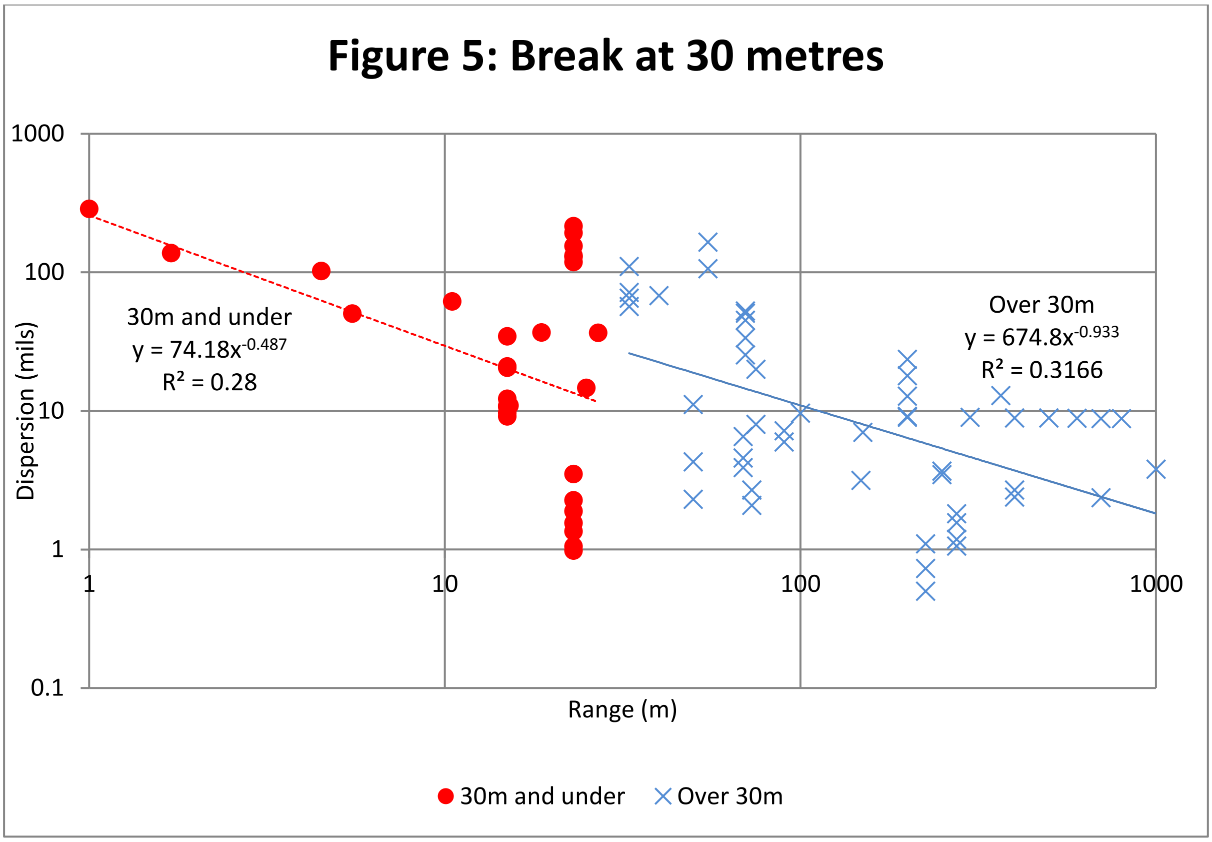


Figure 5: Break at 30 metres
1000
100
10
1
0.1
Dispersion (mils)
1
10
100
1000
Range (m)
30m and under
y = 74.18x-0.487
R² = 0.28
Over 30m
y = 674.8x-0.933
R² = 0.3166
30m and under
Over 30m

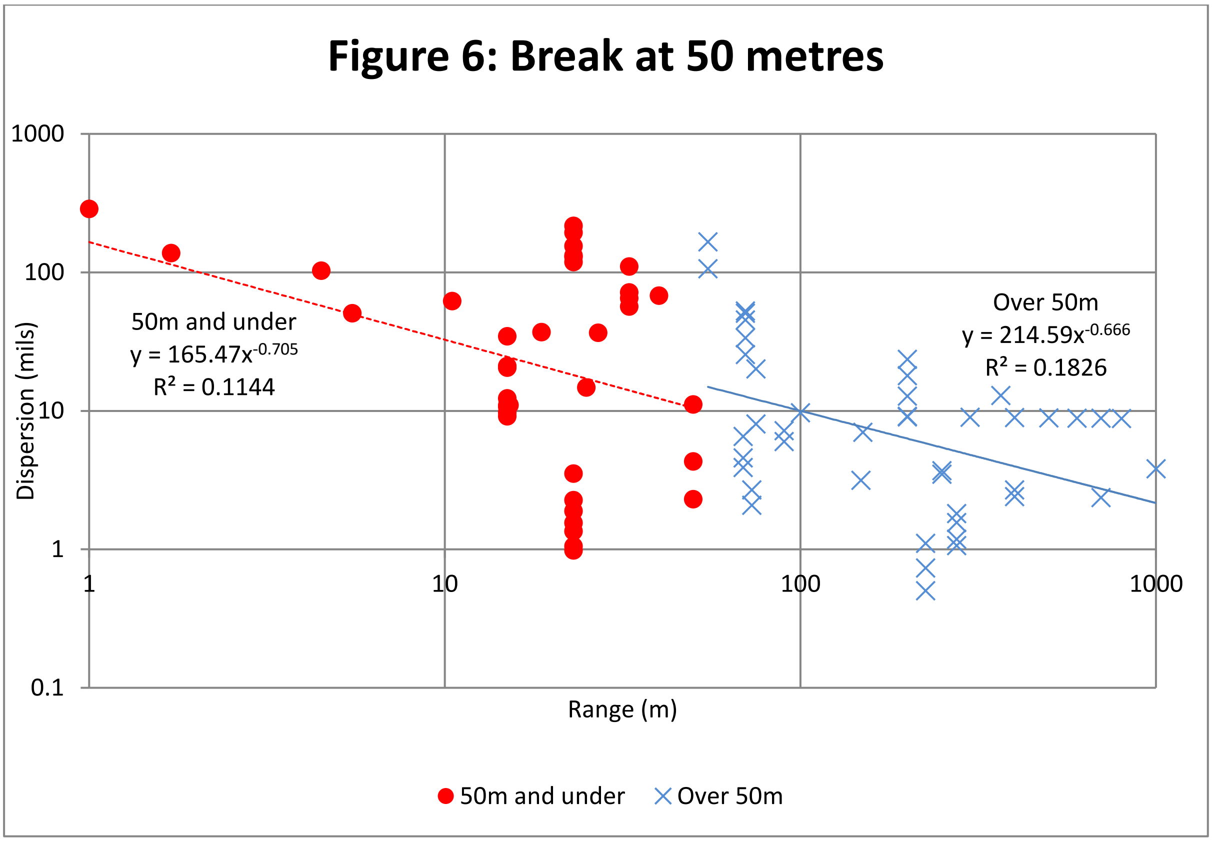


Figure 6: Break at 50 metres
1000
100
10
1
0.1
Dispersion (mils)
1
10
100
1000
Range (m)
50m and under
y = 165.47x-0.705
R² = 0.1144
Over 50m
y = 214.59x-0.666
R² = 0.1826
50m and under
Over 50m

Figure 7: Break at 75 metres

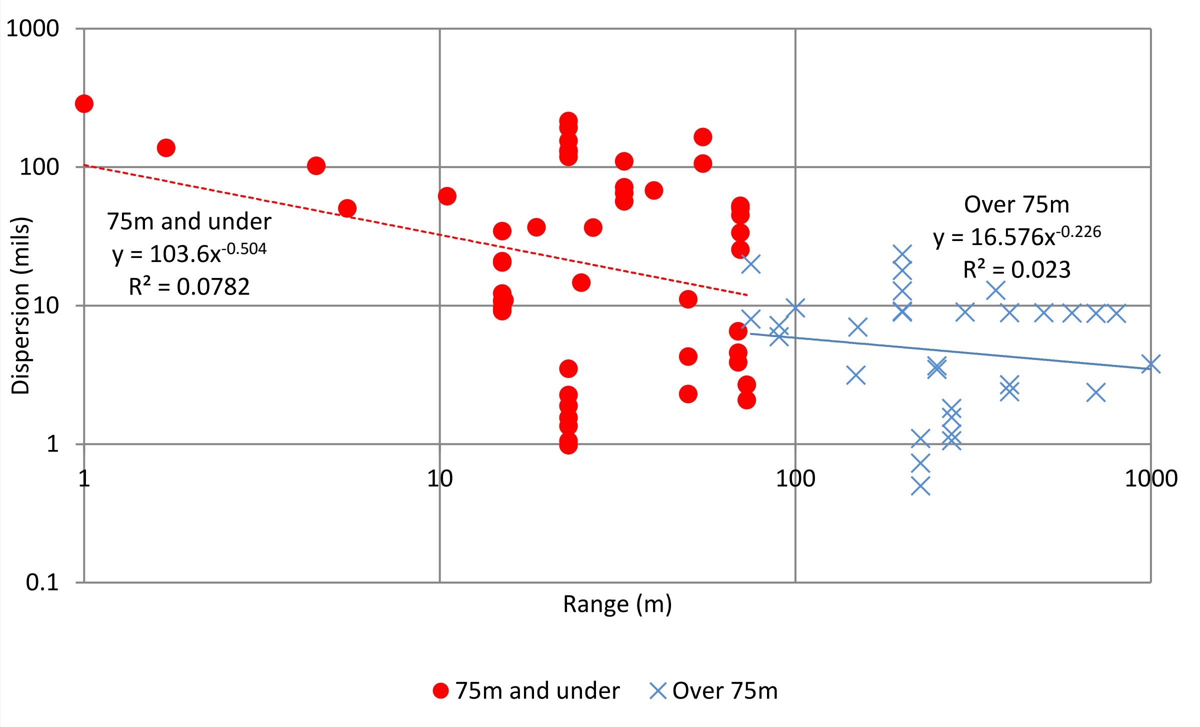
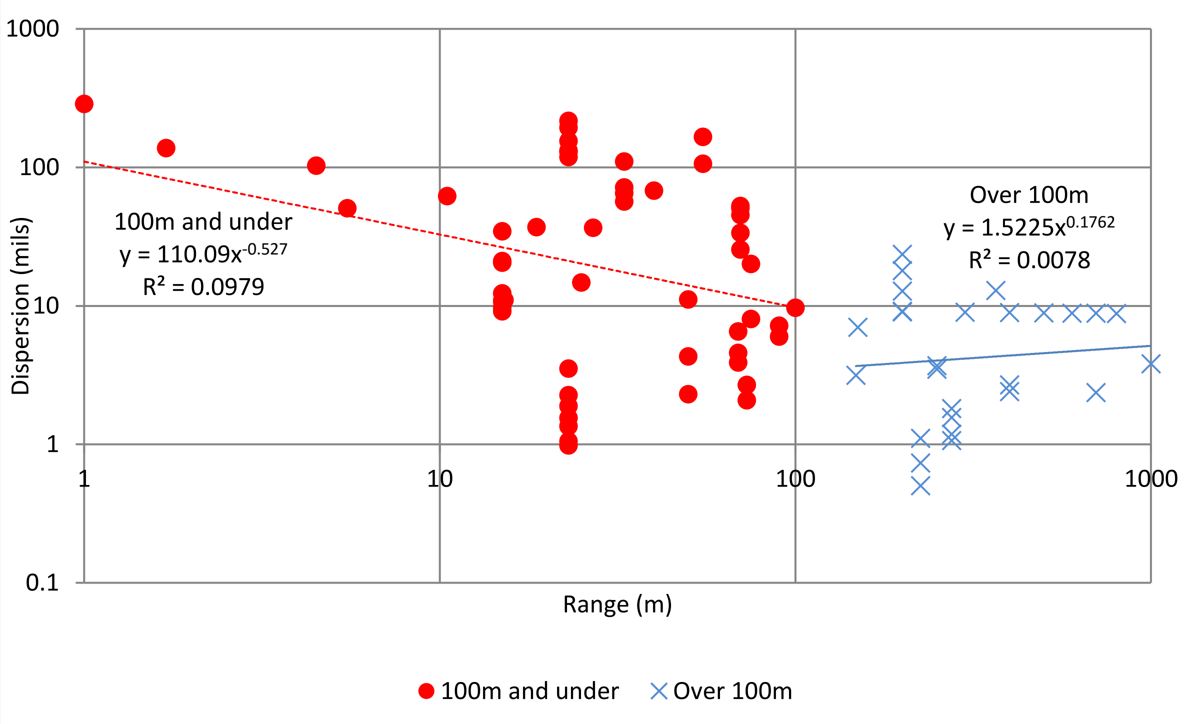


Figure 8: Break at 100 metres



Within the limits of the sparse available data, it has been shown that the angular dispersion of small arms fire increases with target proximity below about 100 metres. This trend is most strongly observable in combat and police shooting data. The trend does not seem to be accounted for by different weapon types used, or whether firing bursts or single shots.

Discussion

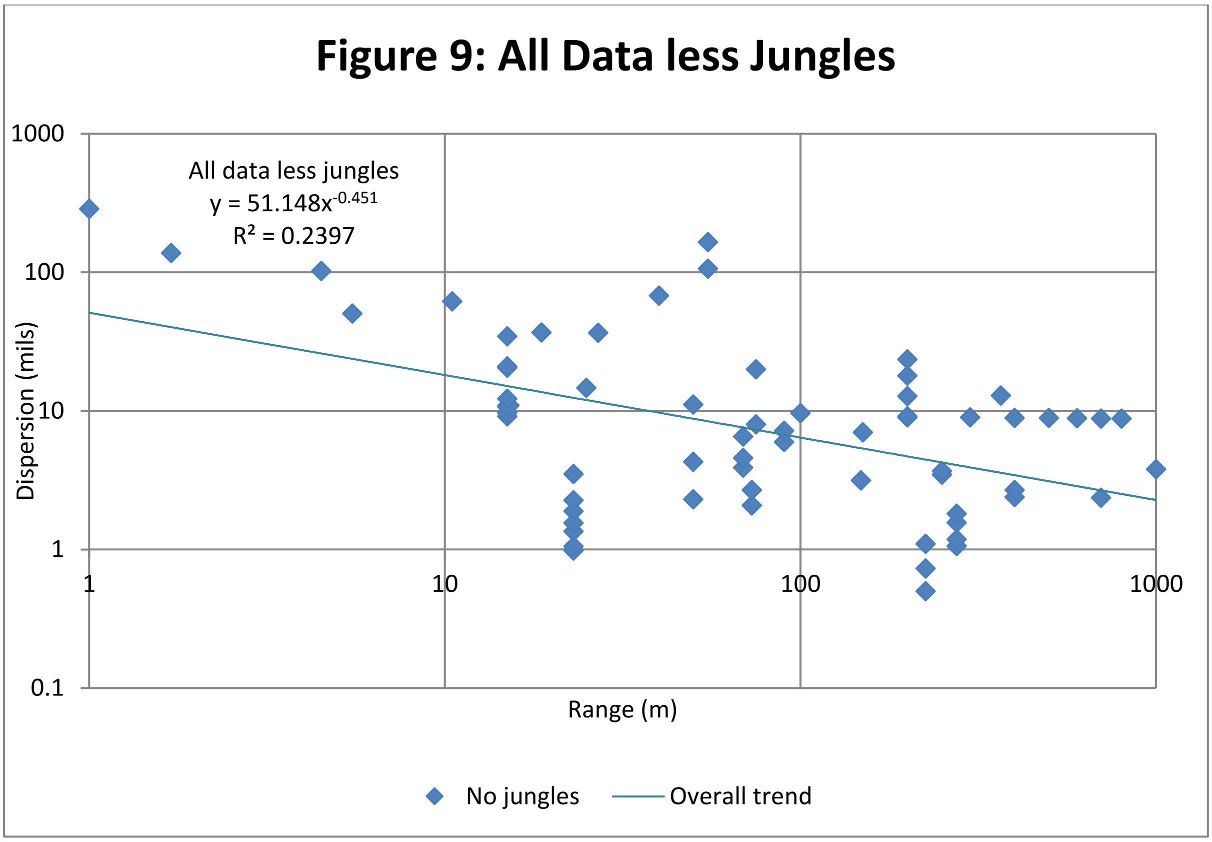
Some of the numbers of rounds required to secure a hit, and hence the derived dispersion, seem large; can it really need over 200 rounds from an SLR to secure one hit in a close-range ambush? Nevertheless it should be borne in mind that the American police departments, 1ATF in Vietnam and British forces in Malaya all handsomely outshot their opponents.

414 of 980 ambushes by 1ATF (42%) occurred at night. 77% of the NYPD police shootings occurred in low light conditions. At night it may be effectively impossible to use the weapon's sights unless a specialist night sight is fitted. In seems that few police shooters used their sights; an NYPD report of 1981 [Aveni 2003] said that in 70% of reported cases, there was no indication that officers had aligned their sights. For 1ATF in the jungle – and doubtless to a considerable extent for British troops in Malaya – a lot of shooting was done without a visible target, but into a likely target area – what the Rhodesian Light Infantry used to call “drake shooting”. The “inverse P(hit)” method produces apparently high dispersions because it treats the question as an aimed fire problem against a visible target. The dispersion figure remains a fair measure of the accuracy with which the fire falls, but it must be borne in mind that a great deal of the angular error represents uncertainty as to the target's position, rather than any inability by the shooter to aim the weapon effectively. This explains, for example, why MGs seem to be associated with such high dispersions at close ranges; they are at least as accurate as the rifles which show much lower dispersions, but, being capable of high rates of fire, are used to “hose down” likely cover.

Considering all the foregoing, it might be argued that the apparent effect of increased dispersion at close range in combat applies only because so many of the close range cases occurred in dense cover, where the position of the target may be quite uncertain. We might assume that the average uncertainty as to a target soldier’s true position was three metres either way – which appears reasonable if he has executed something like the British Army’s contract drill of “Dash, down, crawl, observe, sights, fire.” Plotting the angle subtended by three metres at different ranges produces a curve strikingly similar to that produced by the data from combat engagements.

Against this, there is the point that a strong proximity effect is observed in Police shootings, where no terrain effect or other reason for positional uncertainty is applicable. Further, if all the 1ATF and Malaya data points are removed – rather a shame, as they are by far the best combat data I have found so far – the downward trend of dispersion with range remains obstinately in place, albeit with a slightly less steep gradient; see Figure 9.

A further check is provided by plotting the data points for combat firings of the Panzerfaust. The proximity of a tank may be considered more or less intimidating than that of infantry, but vegetation makes poor concealment for tanks at the close ranges applicable, and it would be highly unusual to employ anti-tank weapons, especially one-shot devices such as Panzerfaust, on the “drake shooting” principle. Notice the similarity between the Panzerfaust trend line and those for Police shootings and other combat shooting, as shown in Figure 2.



Two more points seem to confirm as genuine the effect of increased dispersion with increased proximity. One is that the aiming dispersions given for the SPARTAN II model [Harris 1993] show just such a trend, albeit a very gentle one. Why they do so is not explained in Harris' thesis, which merely states that the figures come from AMSAA. Presumably some AMSAA analyst, at some time, has had evidence to make them believe such an effect exists. The other is the comparison of the covering fire shoots in the US platoon firepower experiment [CDEC 1962]. These shoots – each conducted 20 times – were at ranges of 250 and 400 metres. Weapon and ammunition allocations and target arrays were the same in each case, so all factors seem to have been controlled out except range and time allowed, which was eight minutes at 400m case as against five minutes at 250m. At 400m, both M14 rifles and M60 MGs seem to have shot with at least a mil more accuracy than at 250m. Presumably the slower pace of fire allowed for more accurate aiming, but the ammunition allocations (100 rounds per rifle, 300 rounds per MG) correspond to rates of 20 rds/min for the rifle and 60 rds/min for the MG over five minutes. 20 rds/min was the doctrinal British rapid rate for the SLR, and in the author's experience does not place the shooter under any great time pressure. A rate of 60 rds/min for a machine gun is positively leisurely, being half the British doctrinal rapid rate for the Bren.

That the qualification scores show the tendency is perhaps a surprise, but it is because one standard is for shooting at long range [FM 3-22 9 2008] and the other for CQB [CQB 1961]. The military has long acknowledged the possible need for a transition to quicker, less accurately aimed shooting at close ranges. Captain Stephen Stavers, writing in Infantry Journal for December 1944, says [Stavers 1944]:

> *The function of snap shooting is clear. It is intended for short range (twenty yards and under) combat firing where troops are moving quickly toward each other. In such situations it has been observed that almost every man's instinctive reaction is to fire quickly, without stopping to bring the weapon to his shoulder.*

While this is described as an instinctive reaction, it would also appear to be a rational one in that the shooter is trading the accuracy of aimed fire for the speed of pointed fire. If one believes that a near miss will have a useful suppressive effect, it is rational to trade quite a lot of accuracy for speed. Then again, a stressed shooter may have no choice in the matter: Grossman and Christensen [Grossman & Christensen 2004] report that one of the effects of high doses of adrenalin in combat is loss of close vision. In this case the shooter cannot align the sights of his weapon because he cannot see them, and pointed fire is the only remaining option.

Speight and Rowland [Speight & Rowland 2006] have proposed a model of the typical rural infantry battle that divides the action into three range bands, delimited by the transition ranges 30m and 300m. I suggest that it might be useful to think of each of these range bands as being characterised by a dominant mode of shooting.

Beyond 300m, individual targets are not generally discernible, so areas fire on suspected enemy positions will dominate. This is now the province of mortars and tripod-mounted MGs. In the early 20th century, armies trained to engage massed targets with massed rifle fire at ranges up to 2000 metres. Paul Syms has referred to this as employing the rifles as a “collective machine gun”, and indeed some SMLEs were fitted with dial sights for this type of fire. Hitting an enemy at this range is a matter of density of bullets against density of targets, rather than precision of aim.

At 300m, the attacking infantry unmask, and defenders can commence aimed fire at individual targets. The attackers, with less idea of the whereabouts of the defenders, will still be conducting mostly area fire, with the intention of suppressing the defenders' fire.

Finally, at 30m, the opposing sides enter close combat. One might assume that this is the domain of instinctive rather than aimed shooting; it is also close enough to throw grenades.

It is surely not too fanciful to imagine that a good deal of the increase in dispersion with proximity is due to psychological effects. Indeed two of the data sources used report trials specifically designed to measure the decrease of aiming accuracy caused by physical stress [Scott et al 2015] and sleep deprivation [Jovanović et al 2012]. The shooter may feel more urgency to engage a closer target; the target may increase his speed of movement and reduce his exposure times for closer fire. Both sides may suffer a reduction in accuracy from the suppressive effect of enemy fire, presumably greater at close range. That the effect should appear more pronounced in combat than on trials may be ascribed to greater stress. It may be no more than coincidence, but I am struck by the fact that the apparent “kink” in the trend at about 100 metres corresponds closely to the range attributed by Rowland [Rowland 2006] to the onset of shock from infantry attack.

Conclusions

The most obvious conclusion is that the available data is too sparse to form any statistically rigorous conclusions. However the nature of combat makes it hard to overcome this sparsity, and it would be a shame to disregard what seems to be a genuine effect for lack of statistical rigour.

The most obvious conclusion from the data gathered is to reinforce David Rowland's finding [Rowland 2006] that shooting in combat is much, much worse than it is on the range. Operational researchers should, therefore, be highly sceptical of any results based on range firing that purport to reflect the realities of combat.

It seems clear from the data available that, for one reason or another, the accuracy of small-arms fire decreases with proximity to the target, so that the hitting rate does not increase as much as would otherwise be expected at closer ranges.

Even from the small amount of data collected, it is striking that the decrease in aiming accuracy with proximity is observable in data from all kinds of sources, strongly so for combat and police shootings. The tendency is observed for both burst and single shot fire, and, with the exception of an anomalous result for SMGs, across all weapon types.

It may be possible to account for much of the effect by the shooter's uncertainty as to the precise position of the target in dense vegetation. However, the persistence of the effect when "jungle" cases are removed from the data, and the strong proximity effect seen in Police shootings where the effect of vegetation can be discounted, strongly suggest that positional uncertainty does not completely explain the effect. My own belief is that the psychological effect of enemy proximity must play a large part, but it is not clear how much of this effect is due to enemy fire and how much to his mere presence.

If a psychological stress reaction is at work on weapon aiming accuracy, then an implication for combat modellers is that suppression effects in combat models should be represented by a stress-induced reduction in shooting accuracy, as well as by episodic total cessation of firing. Combat modellers should also consider incorporating a transition to less accurate shooting techniques at some range between 50m and 100m. Combat models might – and some do – incorporate a mechanism for direct-fire engagement of targets whose position is not known with absolute precision. Models intended to show the contribution to combat effectiveness of new sensors are likely to overestimate that contribution if no allowance is made for the fact that small arms fire can be directed effectively at targets less than perfectly acquired, or, in the case of "prophylactic fire", not acquired at all.

The most obvious need for further work is to expand the set of data available. In particular, it is desirable to find more combat data for the longer ranges.

It would be interesting to see if suitable data could be collected from two-sided exercises using Simunition. The threat of the mild pain of Simunition impact provides a better simulacrum of the stress of combat than anything else that can ethically be done in a peacetime exercise, and it would be interesting to see how rounds-per-hit and aiming dispersion compare with the combat data so far collected. It would also be interesting to see if soldiers conducting fire and movement do, indeed, reduce their exposure times with proximity to the enemy is some predictable way. The principal limitation of Simunition is that it is only suitable for use at close range. Some ingenuity would be required to devise and experiment to assess the accuracy of shooters engaging long-ranged targets while themselves being shot at with Simunition.

If it is assumed that it is rational to trade speed for accuracy as the range of engagement closes, then it would be relatively straightforward to devise some simple computer simulation to test the best trade to make. One can conceive of such an experiment being conducted using a continuous scale of speed against accuracy, or a single well-defined transition between aimed and pointed fire. While such simulations do nothing to add to our store of historical data, it would be interesting to see how much of the low accuracy of combat shooting and the apparent proximity effect could potentially be explained as resulting from rational decisions.

It seems clear that there is still a great deal of work to do in many directions before we can claim to have believable numerical models of close combat.

□

References

Mayne 1888	*Infantry Fire Tactics*, Charles Blair Mayne, Gale & Polden, Brompton, 1888
Stavers 1944	*Snap Shooting in Close Combat*, Captain Stephen Stavers USMCR, Infantry Journal 1944 no. 12.
WO 291/153	WO 291/153 *The effectiveness of PIAT shooting*, 1944
WO 291/471	*Weight of small-arms fire needed for various targets*, 1944
WO 291/476	*Comparison of rifle, Bren and Sten guns*, 1944
FB 181 1945	Film Bulletin No. 181, Army Pictorial Service, US Army Signal Corps, 1945
WO 291/965	MORU report no. 23 *Battle Study on Operation Goodwood*, 1946
WO 291/1060	WO 291/1060, *A45 flame guns versus the Panzerfaust weapon*, 1948
WO 291/1668	WO 291/1668, *Performance of small arms weapons including .280 (7mm) rifle, used in machine carbine role in Malaya*, 1953
CQB 1961	Infantry Training Volume III, Ranges and Courses, Pamphlet no. 33, *Close Quarter Shooting*, the War Office, 1961
CDEC 1962	*Rifle Platoon Firepower Experiment*, US Army Combat Development Experimentation Center, Fort Ord, CA, March 1962
Lind et al 1971	*FAST-VAL: A Study of Close Air Support (A Briefing Summarizing the Comparisons of Model with Combat Results and Illustrating the Influence of Supporting Arms on Fire-fight Outcomes)* , J R Lind, K Harris, and S G Spring, R-811-PR, The Rand Corporation, Santa Monica, CA, November 1971
Spring et al 1971	*FAST-VAL: Case Study of an Attack in the DMZ, 8 October 1968*, S G Spring, J R Lind and K Harris, R-818-PR, The Rand Corporation, Santa Monica, CA, November 1971
Shephard et al 1988	*Applied Operations Research: Examples from Defense Assessment*, R W Shephard, D A Hartley, P J Haysman, L Thorpe and M Bathe, Plenum Press, New York, NY, 1988
Harris 1993	*Spartan II: An Instructional High Resolution Land Combat Model*, MSc thesis, Edwin H Harris, Air Force University, March 1993
Robinson 1994	*Successful Simulation: A Practical Approach to Simulation Projects*, Stewart Robinson, McGraw-Hill, London, 1994
Ewell & Hunt 1995	*Sharpening the Combat Edge: The Use of Analysis to Reinforce Military Judgment*, Lt-Gen Julian J Ewell and Maj-Gen Ira A Hunt, jr, Department of the Army, Washington DC, 1995
Aveni 2003	*Officer-Involved Shootings: What We Didn't Know Has Hurt Us*, Thomas J Aveni, Law and Order Magazine, August 2003
Grossman & Christensen 2004	*On Combat: The Psychology and Physiology of Deadly Conflict in War and Peace*, Lt-Col Dave Grossman and Loren W Christensen, PPCT Research Publications, Belleville, IL, 2004
Rowland 2006	*The Stress of Battle: Quantifying Human Performance in Battle*, David Rowland,

	TSO, London, 2006
Speight & Rowland 2006	*Modelling The Rural Infantry Battle: Overall Structure and a Basic Representation of the Approach Battle*, L R Speight and D Rowland, Military Operations Research 11(1):5-26, 2006
FM 3-22 9 2008	FM 3-22 9 2008, *Rifle Marksmanship M16-/M4 Series Weapons*, Department of the Army, Washington, DC, 12 August 2008
Hall & Ross 2009	*Bang on Target: Infantry Marksmanship and Combat Effectiveness in Viet Nam*, Dr Bob Hall and Dr Andrew Ross, Australian Army Journal Vol. VI no. I, pp. 139-156
Zuber 2010	*The Mons Myth*, Terence Zuber, The History Press, Stroud, 2010
Lappi 2012	*Jalkaväen tulen vaikutuksesta* (On the Effect of Infantry Fire), 1954, in *Computational Methods for Tactical Simulations*, Esa Lappi, Helsinki, 2012
Jovanović et al 2012	*The Effects of Basic Military Training on Shooting Tasks in Conditions of Sleep Deprivation*, Mario Jovanović, Goran Sporiš, Josip Šopar, Dražen Harasin and Dario Matika, Kinesiology Vol. 44 no. 1 pp. 31-38, 2012
Murray 2013	*Brains & Bullets: How Psychology Wins Wars*, Leo Murray, Biteback Publishing, London 2013
Scott et al 2015	*The Effect of Stress on Marksmanship*, Adam Scott, Rob Shaul and Sam McCue, Mountain Tactical Institute, Jackson, WY, 2015
PCD undated	*Good to Knows*, Platoon Commanders Division, School of Infantry, Warminster, undated

Annex A: Data sources used and data extracted

Source	Trial type	Trial size	Data given	Assumptions
FM 3-22 9 2008	Qual score	N/A	Hitting rate	
WO 291/476	Range trial	20 rds at 25 yds	90% zone at 25 yds	4ft by 1ft targets
FB 181 1945	Range trial	20 rds SMGs, 30 rds MGs	Hitting rate	Tgt size judged from film
CQB 1961	Qual score	N/A	Hitting rate	Fig 11 target
Scott et al 2015	Range trial	17 subjects, each 30 rds per case	Hitting rate	10-in round tgt modelled as 0.45m square
Zuber 2010	Combat	Not specified, probably a folk figure	Hitting rate	Stated and from beaten zone dims
WO 291/471	OR model	N/A	Hitting rate	Needed to assume troop density
CDEC 1962	Range trial	20 runs per case	Hitting rate	Target mix assumed
Ewell & Hunt 1995	Combat	23 engagements	6 rds/kill, 148m	Target size assumed
Lind et al 1971	OR model	N/A	Ballistic dispersion	
Spring et al 1971	Combat	One battle, 5000 shots for 4-5 cas	Rds/cas	Tgt size assumed for tgts in slit trenches
Lappi 2012	Range trial		Rounds per hit	Tgt size assumed
Harris 1993	OR model	N/A	Dispersion	Figures “from AMSAA”
Jovanović et al 2012	Range trial	19 shooters each 120 rounds, AK, double taps, instinctive shooting, 15m	Hitting rate	Tgt size given, modelled by equal-area square 0.45m a side
Mayne 1888	Combat	One action (Dek Sarak, Afghanistan)	28000 rounds fired, 50 en killed, 400 yds	Tgt size assumed
Hall & Ross, 2009	Combat	About 2800 ambushes and patrols	Shots per kill	Tgt size assumed 42% of ambushes at night
Aveni 2003	Police shootings	NYPD, 1719 incidents Baltimore PD , 75 encounters, 211 shots fired	Hitting rate by range band	Tgt size assumed NYPD 77%, BPD 59% in low light conditions
WO 291/1668	Combat	343 patrols, 315 ambushes	Hitting rate	Tgt size assumed
PCD undated	Combat	One action (Rasau, Malaya)	6000 en rds fired, 7 friendly cas, 2081 friendly rds fired, en cas unknown, 60 yds	Tgt size assumed 1 en cas assumed

Error (mils)	Range (metres)	Environment	Weapon	Weapon type	Remarks	Source
0.5	225	Qual firing	M16/M4	Rifle	Expert, KD range	FM 3-22 9 2008
0.73	225	Qual firing	M16/M4	Rifle	Sharpshooter, KD	FM 3-22 9 2008
0.98	23	Range trial	Bren	MG	Single shot	WO 291/476
1.05	23	Range trial	.303 rifle	Rifle	Wpn rested	WO 291/476
1.06	275	Range trial	M1917	MG	Double E tgt	FB 181 1945
1.1	225	Qual firing	M16/M4	Rifle	Marksman, KD	FM 3-22 9 2008
1.18	275	Range trial	M1919	MG	Double E tgt	FB 181 1945
1.35	23	Range trial	Bren	MG	Bursts	WO 291/476
1.55	23	Range trial	Sten	SMG	Singles, rested	WO 291/476
1.56	275	Range trial	sMG-42	MG	Double E tgt	FB 181 1945
1.81	275	Field trial	lMG-34	MG	Double E tgt	FB 181 1945
1.89	23	Range trial	Sten	SMG	Singles, unrested	WO 291/476
2.08	73	Range trial	AR15	Rifle	Unstressed	Scott et al 2015
2.26	23	Range trial	Sten	SMG	Bursts, rested	WO 291/476
2.3	50	Qual firing	SLR	Rifle	High standard	CQB 1961
2.36	700	Combat	Mauser 98	Rifle	From beaten zone	Zuber 2010
2.39	400	Range trial	M14	Rifle	Tgt size assumed	CDEC 1962 (CF)
2.68	400	Range trial	M60	MG	Tgt size assumed	CDEC 1962 (CF)
2.68	73	Range trial	AR15	Rifle	Stressed	Scott et al 2015
3.15	148	Combat	M14	Rifle	Dark, Sniperscope	Ewell & Hunt 1995
3.47	250	Range trial	M14	Rifle	Tgt size assumed	CDEC 1962 (CF)
3.51	23	Range trial	Sten	SMG	Bursts, unrested	WO 291/476
3.68	250	Range trial	M60	MG	Tgt size assumed	CDEC 1962 (CF)
3.8	1000	Combat	Mauser 98	Rifle	From hitting rate	Zuber 2010
3.89	69	Field trial	M3	SMG	E target	FB 181 1945
4.3	50	Qual firing	SLR	Rifle	Pass standard	CQB 1961
4.57	69	Range trial	Thompson	SMG	E target	FB 181 1945
5.98	90	Range trial	M14	Rifle	Tgt size assumed	CDEC 1962 (MF)
6.53	69	Range trial	MP40	SMG	E target	FB 181 1945
7.0	150	OR model	rifle/Bren	Rifle/MG	Tp dens assumed	WO 291/471
7.19	90	Range trial	M60	MG	Tgt size assumed	CDEC 1962 (MF)
8.0	75	OR model	M16 or AK	Rifle	From foxhole	Lind et al 1971
8.78	800	OR model	M16	Rifle	Prone	Harris 1993
8.81	700	OR model	M16	Rifle	Prone	Harris 1993
8.84	600	OR model	M16	Rifle	Prone	Harris 1993
8.87	500	OR model	M16	Rifle	Prone	Harris 1993
8.9	400	OR model	M16	Rifle	Prone	Harris 1993

Error (mils)	Range (metres)	Environment	Weapon	Weapon type	Remarks	Source
8.97	300	OR model	M16	Rifle	Prone	Harris 1993
9.0	200	Range trial	7.62 rifle	Rifle	Tgt size assumed	Lappi 2012
9.12	15	Range trial	AK	Rifle	Trained, rested	Jovanović et al 2012
9.12	200	OR model	M16	Rifle	Prone	Harris 1993
9.64	100	OR model	M16	Rifle	Prone	Harris 1993
9.69	15	Range trial	AK	Rifle	Untrained, rested	Jovanović et al 2012
10.7	15	Range trial	AK	Rifle	Trained, sleepless	Jovanović et al 2012
10.9	15	Range trial	.303 rifle	Rifle	Moving target	WO 291/476
10.97	15.2	Police	Handgun	Handgun	Tgt size assumed	Aveni 2003
11.1	50	OR model	M16	Rifle	Prone	Harris 1993
12.25	15	Range trial	AK	Rifle	Untrained, sleepless	Jovanović et al 2012
12.75	200	Range trial	SVT	Rifle	Tgt size assumed	Lappi 2012
12.89	366	Combat	Martini	Rifle	Tgt size assumed	Mayne 1888
14.7	25	OR model	M16	Rifle	Prone	Harris 1993
17.91	200	Range trial	Lahti AR	MG	Tgt size assumed	Lappi 2012
20.0	75	OR model	M16 or AK	Rifle	From hip	Lind et al 1971
20.5	15	Range trial	Sten	SMG	Bursts, Mvg tgt	WO 291/476
20.7	15	Range trial	Sten	SMG	Singles, Mvg tgt	WO 291/476
21	15	Range trial	Bren	Rifle	Singles, Mvg tgt	WO 291/476
23.51	200	Range trial	Suomi	SMG	Tgt size assumed	Lappi 2012
25.4	70	Combat	US carbine	Rifle	Tgt size assumed, patrol	WO 291/1668
33.65	70	Combat	No. 5 rifle	Rifle	Tgt size assumed, patrol	WO 291/1668
34.5	15	Range trial	Bren	MG	Bursts, Mvg tgt	WO 291/476
36.55	27	Police	Handgun	Handgun	Tgt size assumed, NYPD	Aveni 2003
36.9	18.7	Police	Handgun	Handgun	Tgt size assumed, NYPD	Aveni 2003
45.19	70	Combat	Owen	SMG	Tgt size assumed, patrol	WO 291/1668
50.45	5.5	Police	Handgun	Handgun	Tgt size assumed, BPD	Aveni 2003
50.69	70	Combat	Sten	SMG	Tgt size assumed, patrol	WO 291/1668
52.5	70	Combat	Bren	MG	Tgt size assumed, patrol	WO 291/1668
56.53	33	Combat	US carbine	Rifle	Tgt size assumed, ambush	WO 291/1668
61.79	10.5	Police	Handgun	Handgun	Tgt size assumed, NYPD	Aveni 2003
64.95	33	Combat	No. 5 rifle	Rifle	Tgt size assumed, ambush	WO 291/1668
67.79	40	Combat	AK /RPD	Rifle/MG	Tgt size assumed, slit trench	Spring et al 1971
71.64	33	Combat	Bren	MG	Tgt size assumed, ambush	WO 291/1668
102.47	4.5	Police	Handgun	Handgun	Tgt size assumed, NYPD	Aveni 2003
106.14	55	Combat	Mixed	Mixed	Tgt size assumed	PCD undated
110.05	33	Combat	Owen/Sten	SMG	Tgt size assumed, ambush	WO 291/1668

Error (mils)	Range (metres)	Environment	Weapon	Weapon type	Remarks	Source
118.43	23	Combat	SLR	Rifle	Tgt size assumed, patrol	Hall & Ross 2009
129.07	23	Combat	SLR	Rifle	Tgt size assumed, ambush	Hall & Ross 2009
131.95	23	Combat	M16	Rifle	Tgt size assumed, patrol	Hall & Ross 2009
137.79	1.7	Police	Handgun	Handgun	Tgt size assumed, BPD	Aveni 2003
154.77	23	Combat	M16	Rifle	Tgt size assumed, ambush	Hall & Ross 2009
165.46	55	Combat	Mixed	Mixed	Tgt size and 1 cas assumed	PCD undated
192.85	23	Combat	M60	MG	Tgt size assumed, ambush	Hall & Ross 2009
215.68	23	Combat	M60	MG	Tgt size assumed, patrol	Hall & Ross 2009
286.9	1	Police	Handgun	Handgun	Tgt size assumed, NYPD	Aveni 2003